DEFENCE R&D DÉFENSE

Canadian Forces Glove Fit Study: Fit Assessment of In-Service Chemical Warfare Lightweight Glove and Molded Glove Prototype

Sylvia Weihrer
Kinection, 8 Banting Crescent, Kanata, Ontario, K2K 1P4

Julie Tremblay-Lutter
Defence Research Establishment Suffield

Technical Report
DRES TR 2000-003
September 2000

National Defence Défense nationale

Canada

Canadian Forces Glove Fit Study: Fit Assessment of In-Service Chemical Warfare Lightweight Glove and Molded Glove Prototype

Sylvia Weihrer
Kinection, 8 Banting Crescent, Kanata, Ontario, K2K 1P4

Julie Tremblay-Lutter
Defence Research Establishment Suffield

Defence Research Establishment Suffield

Technical Report

DRES TR 2000-003

September 2000

102-01337/

Author

Julie Tremblay-Lutter

Approved by

Dr. C. Boulet
Head/Chemical and Biological Defence Section

Approved for release by

Dr. R. Herring
Chair DRP/DRES

© Her Majesty the Queen as represented by the Minister of National Defence, 2000
© Sa majesté la reine, représentée par le ministre de la Défense nationale, 2000

Abstract

The Defence Research Establishment Suffield (DRES) has been conducting research in a number of areas to address deficiencies in dipped chemical defence gloves, through innovation in moulding technologies, polymer formulations, and advanced concepts in glove design. In keeping with a Functional Design approach [1], DRES focused on anthropometry and critical ease requirements to optimize manual performance of gloved hands. A *Canadian Forces Glove Fit Study* was undertaken in order to develop a comprehensive database of hand dimensions of male and female military personnel for application to the development of a new CB molded glove. The study was undertaken in three phases: definition of the hand dimensions of the CF population; assessment of the range and quality of fit provided by three protective glove systems; and development of an integrated CB glove sizing system and derivation of 44 design dimensions for the CB glove computer models. A total of 358 male CF personnel and 178 female CF personnel participated in the study.

This report presents the results from the assessments of quality of fit of the three glove systems: the Canadian chemical warfare (CW) lightweight glove, a prototype molded CB protective glove, and the prototype glove worn with a liner underlayer. Subjective questionnaires were used to gather information on perceptions of overall fit, task performance capabilities and specific fit problem areas. The current Canadian Forces five-size system was found to be unsatisfactory in meeting the sizing needs of the CF personnel. The need to integrate anthropometry in glove design is demonstrated through the evaluation of one size of a new molded glove.

Résumé

Le Centre de recherches pour la défense Suffield (CRDS) effectue des recherches dans plusieurs domaines pour corriger certains défauts des gants de défense chimique manufacturés par trempage en élaborant de nouvelles techniques de moulage, de nouvelles formules de polymères et de nouveaux concepts pour le design des gants. Pour respecter une approche de Conception fonctionnelle [1], le CRDS s'est concentré sur les exigences anthropométriques et les problèmes d'aisance dans le but d'optimiser la dextérité manuelle lors du port des gants. Une *Étude sur l'ajustement des gants des Forces canadiennes* (*Canadian Forces Glove Fit Study*) a été menée afin de créer une base de données exhaustive sur les dimensions des mains du personnel militaire masculin et féminin qui pourrait servir à l'élaboration d'un nouveau type de gants moulés CB. L'étude comportait trois étapes : détermination des dimensions des mains des membres des FC; évaluation de la portée et de la qualité de l'ajustement de trois types de gants de protection; élaboration d'un système intégré de grandeurs de gants CB et dérivation de 44 grandeurs de conception pour les modèles informatiques de gants CB. Au total, 358 hommes et 178 femmes membres du personnel des FC ont participé à l'étude

Le présent rapport traite des résultats de l'évaluation de la qualité de l'ajustement de trois types de gants : les gants légers de guerre chimique canadiens, un prototype de gants de protection CB moulés et le même prototype de gants avec doublure. Des questionnaires subjectifs ont été utilisés pour recueillir des données sur la perception de l'ajustement en général, sur la capacité d'effectuer des tâches en portant des gants et sur des problèmes d'ajustement précis. Le système à cinq grandeurs utilisé actuellement par les FC a été jugé insatisfaisant pour répondre aux besoins du personnel des FC. Le besoin d'intégrer des données anthropométriques au processus de conception des gants a été démontré par l'évaluation d'une seule grandeur de nouveaux gants moulés.

Executive summary

In a chemical and biological (CB) threat environment, dipped polymer gloves have been an important part of individual protective equipment. While providing acceptable protection against toxic agents, a number of deficiencies have been identified with dipped gloves: they have inadequate resistance to petroleum, oils and lubricants (POL's), poor physical properties (especially poor tear strength), they interfere with manual dexterity, lead to accumulation of hand perspiration and are expensive to produce. The Defence Research Establishment Suffield (DRES) has been conducting research in a number of areas to address these deficiencies through innovation in moulding technologies, new polymer formulations, and new concepts in glove design, liners and selectively permeable glove materials.

In keeping with a *Functional Design* approach [1], DRES has focused on anthropometry requirements to optimize manual performance of gloved hands. During the glove concept development, critical ease considerations identified in glove fit and dexterity trials [2] were also integrated into the glove design. The *Canadian Forces (CF) Glove Fit Study* was undertaken in order to develop a comprehensive database of hand dimensions for male and female CF personnel that could be applied to the development of a new glove. Another component of the study was to evaluate the range and quality of fit provided by three protective glove systems: the CF in-service chemical warfare (CW) lightweight glove, a prototype molded CB protective glove, and the prototype glove worn with a liner underlayer. Under a contractual arrangement, Kinection carried out the anthropometry surveys, glove fit assessments, and participated in the integration of anthropometry data into a DRES generated CAD model to create the industrial glove design.

Data collection activities for the *CF Glove Fit Study* were completed between March and July of 1995. These activities took place at three locations: CF Base Halifax, CF Base Petawawa and National Defence Headquarters (NDHQ) Ottawa. The resulting study sample was comprised of 536 CF personnel (358 males and 178 females). Discussions between Department of National Defence and a Canadian Glove Manufacturer with regards to negotiations leading to a License Agreement for the production of the new CB moulded glove, delayed the release of the information related to the *CF Glove Fit Study* and CAD model development.

The results of the *CF Glove Fit Study* are presented in a series of three reports. This report presents the fit assessment results for the in-service CW lightweight glove and the prototype molded CB glove worn with and without a liner underlayer. With the use of subjective questionnaires, data was collected on perception of overall fit, task performance capabilities and specific fit problems from a representative sample of the CF population.

For the **in-service CW lightweight glove**, 78.2% of **males** met an acceptable fit criteria. The males were normally distributed among the five in-service glove sizes with the medium size representing the most popular size. The extra-small and small sizes demonstrated superior fit compared to the medium, large and extra-large sizes. The most frequent fit problem with the larger glove sizes was excessive finger lengths. For **females**, 69 7% of females met acceptable fit criteria. Of those females, most selected the extra-small size as best fitting. There was a clear need for smaller fitting gloves for the female CF personnel.

The **prototype CB protective glove** which was available in only one size at the time of this study demonstrated a wide range of fit for male CF personnel. Fifty-six percent (56.4%) met acceptable fit criteria without the liner underlayer and 59.8% met acceptable fit criteria with the liner and glove combination. The prototype size was centrally situated within the range of male hand dimensions and most closely resembled the medium and large in-service glove sizes. The prototype glove provided an acceptable fit to 21.3% of the **female** personnel when worn without a liner

From the *CF Glove Fit Study* it was concluded that the in-service lightweight protective glove sizing system provides an "acceptable fit" to only a limited portion of the CF population. For males, the finger lengths in the larger glove sizes where consistently too long For females the in-service gloves did not offer sizes that were small enough to provide acceptable fit. One of the key requirements in developing clothing for the protection of soldiers is to ensure acceptable fit of 90-95 % of both male and female user-population to ensure operational effectiveness. From a sizing point of view, the in-service CF lightweight CB gloves were considered unacceptable.

In spite of the limitation of having only one size of the moulded glove available for evaluation during this study, this size alone provided acceptable fit for 56.4 % of male when the glove was worn without a liner, and 59.8% when worn with a liner. In contrast, the highest male tariff for any one size with the in-service glove was 28.8% (medium size). In analyzing the data it was concluded that the CF five size system could not be used for the new CB glove. Based on compilation of data from the *CF Glove Fit Study*, a seven size system was developed to better meet the needs of a military population and is being adopted for the new CB moulded glove [3].

Weihrer, S., Tremblay-Lutter, J. 2000. Canadian Forces Glove Fit Study: Fit Assessment of In-Service Chemical Warfare Lightweight Glove and Molded Glove Prototype. DRES TR 2000-003. Defence Research Establishment Suffield.

Sommaire

Les gants de polymère manufacturés par trempage ont toujours constitué une partie importante de l'équipement de protection individuelle en situation de menace chimique et biologique (CB). Même si ces gants offrent une protection acceptable contre les agents toxiques, ils ont quand même certains défauts : ils ne sont pas assez résistants aux produits pétroliers, ils ont de faibles caractéristiques physiques (plus particulièrement une faible résistance à la déchirure), ils nuisent à la dextérité manuelle, ils entraînent une accumulation de sueur sur les mains et ils sont très coûteux à produire. Le Centre de recherches pour la défense Suffield (CRDS) effectue des recherches dans plusieurs domaines pour corriger ces défauts en élaborant de nouvelles techniques de moulage, de nouvelles formules de polymères et de nouveaux concepts pour le design des gants, la fabrication de doublures et la création de matériaux à perméabilité sélective.

Pour respecter l'approche de la *Conception fonctionnelle* [1], le CRDS s'est concentré sur les exigences anthropométriques dans le but d'optimiser la dextérité manuelle lors du port des gants. Lors de l'élaboration du design des gants, les problèmes d'aisance identifiés lors des essais d'ajustement des gants et de dextérité [2] ont été pris en considération L'*Étude sur l'ajustement des gants des Forces canadiennes (FC)* (*Canadian Forces (CF) Glove Fit Study*) a été menée afin de créer une base de données exhaustive sur les dimensions des mains du personnel masculin et féminin des FC qui pourrait servir à l'élaboration d'un nouveau type de gants. L'étude avait aussi pour but d'évaluer la portée et la qualité de l'ajustement de trois types de gants de protection : les gants légers de guerre chimique réglementaires des FC, un prototype de gants de protection CB moulés et le même prototype de gants avec doublure. Suite à un accord contractuel, la firme Kinection a effectué les études en anthropométrie et les évaluations d'ajustement des gants et a participé à l'intégration des données d'anthropométrie dans un modèle de CAO du CRDS afin de créer le modèle de gant industriel.

La collecte de données pour l'*Étude sur l'ajustement des gants des FC* s'est effectuée entre mars et juillet 1995 aux bases des FC d'Halifax et de Petawawa ainsi qu'au Quartier général de la Défense nationale (QGDN) à Ottawa. L'échantillonnage final comptait 536 membres du personnel des FC (358 hommes et 178 femmes). Des discussions et des négociations entre le ministère de la Défense nationale et un fabricant de gants canadien pour l'octroi d'un contrat de licence pour la production des nouveaux gants moulés CB ont retardé la diffusion des renseignements sur l'*Étude sur l'ajustement des gants des FC* et l'élaboration du modèle de CAO.

Les résultats de l'*Étude sur l'ajustement des gants des FC* sont regroupés sous trois rapports. Le présent rapport traite des résultats de l'évaluation de l'ajustement des gants légers de guerre chimique réglementaires des FC et du prototype de gants CB moulés avec et sans doublure. À l'aide de questionnaires subjectifs, des données sur la perception de l'ajustement en général, sur la capacité d'effectuer des tâches en portant

des gants et sur des problèmes d'ajustement précis ont été recueillies auprès d'un échantillonnage représentatif de membres des FC.

Pour les **gants légers de guerre chimique réglementaires**, 78,2 % des **hommes ont jugé** que l'ajustement était acceptable. Les hommes étaient répartis normalement parmi les cinq grandeurs de gants réglementaires, la grandeur moyenne étant la plus populaire. Les gants très petits et petits offraient un ajustement supérieur aux autres gants (moyens, grands et très grands) Le problème d'ajustement le plus fréquent des gants plus grands était la longueur excessive des doigts. En ce qui concerne les **femmes**, 69,7 % d'entre elles ont jugé que l'ajustement était acceptable et parmi celles-ci la majorité a jugé que les gants très petits offraient le meilleur ajustement. Il était clair que le personnel féminin des FC avait besoin de gants plus petits.

Pour le **prototype de gants de protection CB**, qui n'était disponible qu'en une seule grandeur au moment de l'étude, les résultats sur la qualité de l'ajustement était très variés parmi le personnel masculin des FC. Cinquante six pour cent (56,4 %) des hommes ont jugé que l'ajustement était acceptable sans la doublure et 59,8 % ont jugé que l'ajustement était acceptable avec la doublure. La grandeur du prototype se situait au centre de la gamme de dimensions de mains d'hommes et se rapprochait plus des grandeurs moyenne et grande des gants réglementaires. En ce qui concerne les **femmes**, 21,3 % ont jugé que l'ajustement du prototype de gants était acceptable sans la doublure.

L'*Étude sur l'ajustement des gants des FC* a permis de conclure que la gamme de grandeurs des gants de protection légers réglementaires fournissait un « ajustement acceptable » à une portion limitée seulement des membres des FC. Pour les hommes, la longueur des doigts des gants plus grands était beaucoup trop longue. Pour les femmes, les gants réglementaires n'étaient pas disponibles dans des grandeurs suffisamment petites pour offrir un ajustement acceptable. Une des principales exigences à respecter lors de l'élaboration de vêtements de protection pour les soldats est de faire en sorte que l'ajustement soit acceptable pour 90 à 95 % des utilisateurs masculins et féminins, afin d'assurer une efficacité opérationnelle. Du point de vue des grandeurs, les gants légers CB réglementaires des FC ont été jugés inacceptables.

Malgré le fait qu'une seule grandeur de gants moulés était disponible pour évaluation lors de l'étude, celle-ci semblait offrir un ajustement acceptable pour 56,4 % des hommes lorsque les gants étaient portés sans doublure et pour 59,8 % lorsqu'ils étaient portés avec doublure. Par contre, le pourcentage le plus élevé obtenu chez les hommes pour une seule grandeur de gants réglementaires était 28,8 % (grandeur moyenne). L'analyse des données a permis de conclure que le système à cinq grandeurs des FC ne pouvait être utilisé pour les nouveaux gants CB. Après compilation des données de l'*Étude sur l'ajustement des gants des FC*, un système à sept grandeurs a été mis au point pour mieux répondre aux besoins du personnel militaire. Ce système sera adopté pour les nouveaux gants moulés CB [3].

Weihrer, S., Tremblay-Lutter, J. 2000. Canadian Forces Glove Fit Study: Fit Assessment of In-Service Chemical Warfare Lightweight Glove and Molded Glove Prototype. DRES TR 2000-003. Centre de recherches pour la défense Suffield.

Table of contents

Abstract i

Executive summary iii

Sommaire v

Table of contents vii

List of figures x

1. Introduction 1
   - 1.1 Objectives of the study 1
   - 1.2 CF glove fit study reports 2

2. Methodology 2
   - 2.1 Glove fit assessment 2
     - 2.1.1 Glove systems 3
     - 2.1.2 Glove fit assessment protocol 3
       - 2.1.2.1 Fit assessment of in-service CW lightweight glove 4
       - 2.1.2.2 Fit assessment of unlined prototype CB protective glove 4
       - 2.1.2.3 Fit assessment of lined prototype CB protective glove 4
   - 2.2 Study protocol 5

3. Results & discussion 5
   - 3.1 Criteria for acceptable glove fit 6
   - 3.2 Evaluation of the in-service glove sizing system 6
     - 3.2.1 Size distributions for the in-service glove 7
     - 3.2.2 Nature of in-service glove fit 10
       - 3.2.2.1 Overall fit ratings for the in-service glove 10
       - 3.2.2.2 Fit problem areas for the in-service glove 13
         - 3.2.2.2.1. Fit problems for male subjects 14
         - 3.2.2.2.2. Fit problems for female personnel 17
       - 3.2.2.3 Nature of in-service glove fit – Conclusions 20

3.3 Evaluation of the unlined prototype glove 21
3.3.1 Range of unlined prototype glove fit 21
3.3.2 Nature of fit for the unlined prototype glove 22
3.3.2.1 Overall fit ratings for the unlined prototype glove 22
3.3.2.2 Fit problem areas for the unlined prototype glove 23
3.3.2.2.1. Fit problems for male subjects 23
3.3.2 2.2. Fit problems for female subjects 25
3.3.2.2 3. Nature of unlined prototype glove fit – conclusions 28
3.3.3 Location of prototype glove size relative to in-service CW glove sizes 28
3.3.3.1 Hand dimensions and glove fit 29
3.4 Evaluation of the lined prototype glove 33
3.4.1 Glove liner fit 33
3.4.2 Range of lined prototype glove fit 35
3.4.3 Nature of fit for the lined prototype glove 40
3.4.3.1 Overall fit ratings for the lined prototype glove 40
Males 40
Females 40
3.4.3.2 Fit problem areas for the lined prototype glove 41
3.4.3.2.1. Fit problems for male subjects 41
3.4.3.2.2. Fit problems for female subjects 43
3.4.3.3 Nature of lined prototype glove fit – Conclusions 45

4. Summary & conclusions 47
4.1 Question 1 – Range of in-service CW lightweight glove fit 47
4.1.1 Range of in-service glove fit for males 47
4.1.2 Range of in-service glove fit for females 48
4.2 Question 2 – Nature of fit provided by in-service CW lightweight glove 48
4.2.1 Overall fit ratings for in-service glove 48
4.2.2 Area specific fit problems for in-service glove 49
4.2.2.1 Males 49
4.2.2.2 Females 49
4.3 Question 3 – Range of fit provided by the unlined prototype CB glove 50
4.4 Question 4 – Nature of fit provided by the unlined prototype CB glove 51
4.4.1 Overall fit ratings for unlined prototype glove 51
4.4.2 Area specific fit problems for the unlined prototype glove 52

4.4.2 1 Males 52
4.4.2.2 Females 52
4.5 Question 5 – Location of unlined prototype CB protective glove within in-service glove sizing system 52
4.6 Question 6 – Effect of glove liner on fit of CB protective prototype glove ... 53
4.6.1 Range of liner fit 53
4.6.2 Range of lined prototype glove fit 53
4.6.3 Overall fit ratings for lined prototype glove 54
4.6.4 Fit problem areas for lined prototype glove 54
4.6.4.1 Males 54
4.6.4 2 Females 54
4.7 Conclusions 55
5. References 57
Annex A 59
Annex B 67
Distribution list 73

List of figures

Figure 3-1. Male best-fitting size distributions for in-service glove – complete sample and acceptable fit group. 9

Figure 3-2. Female best-fitting size distributions for in-service glove – complete sample and acceptable fit group. 9

Figure 3-3. Response format for fit problem area identification and qualification 13

Figure 3-4. Frequency of area specific fit problems for male subjects within the in-service CW glove acceptable fit group, all sizes considered. 15

Figure 3-5. Frequency of area specific fit problems for male subjects within the in-service CW glove unacceptable fit group, all sizes considered. 15

Figure 3-6. Frequency of area specific fit problems for female subjects within the in-service CW glove acceptable fit group, all sizes considered. 19

Figure 3-7. Frequency of area specific fit problems for female subjects within the in-service CW glove unacceptable fit group, all sizes considered. 19

Figure 3-8. Frequency of area specific fit problems for male subjects within the unlined prototype glove acceptable fit group. 24

Figure 3-9. Frequency of area specific fit problems for male subjects within the unlined prototype glove unacceptable fit group. 24

Figure 3-10. Frequency of area specific fit problems for female subjects within the unlined prototype glove acceptable fit group. 27

Figure 3-11. Frequency of area specific fit problems for female subjects within the unlined prototype glove unacceptable fit group. 27

Figure 3-12. Male size distributions for glove liner. 34

Figure 3-13. Female size distributions for glove liner. 34

Figure 3-14. Partitioning of male subjects for lined and unlined prototype gloves between acceptable and unacceptable fit groups. 37

Figure 3-15. Frequency of area specific fit problems for male subjects within the lined prototype glove acceptable fit group. 42

Figure 3-16. Frequency of area specific fit problems for male subjects within the lined prototype glove unacceptable fit group. 42

Figure 3-17. Frequency of area specific fit problems for female subjects within the lined prototype glove acceptable fit group... . .. .46

Figure 3-18. Frequency of area specific fit problems for female subjects within the lined prototype glove unacceptable fit group..... .. .. .46

Figure B-5.1. Five sizes of in-service CW lightweight gloves. 69

Figure B-5.2. One size prototype CB protective glove. ..... .69

Figure B-5.3. Medium size in-service CW lightweight glove (left), prototype CB protective glove (middle) and large size in-service CW lightweight glove (right)..... 70

Figure B-5.4. Glove liner – four sizes. .... .70

Figure B-5.5 Liner size selection at CFB Halifax. 71

Figure B-5.6. Prototype glove evaluation at CFB Halifax. .. .. .71

List of tables

Table 3-1. Size distributions for the in-service glove.. 8

Table 3-2. Mean overall fit ratings for the in-service glove.....12

Table 3-3. Mean male fit problem area ratings for the in-service CW glove.....16

Table 3-4. Mean female fit problem area ratings for the in-service CW glove.....20

Table 3-5. Mean overall fit ratings for unlined prototype and in-service gloves 22

Table 3-6. Mean fit problem area ratings for unlined prototype and in-service gloves 26

Table 3-7. Distribution for acceptable fit unlined prototype glove group by in-service glove size 29

Table 3-8. Male hand dimension summary statistics by handwear condition.... 31

Table 3-9. Female hand dimension summary statistics by handwear condition 32

Table 3-10. Distributions for lined and unlined prototype glove acceptable fit groups by in-service glove size..... .... .36

Table 3-11. Mean hand dimensions for partitions of male lined and unlined prototype glove groups.. 38

Table 3-12 Mean overall fit ratings for lined prototype, unlined prototype and in-service gloves 40

Table 3-13 Mean fit problem area ratings for lined prototype and unlined prototype gloves 44

1. Introduction

The Department of National Defence has been investigating new technologies for producing a molded chemical biological (CB) protective glove for several years. This research has taken place at the Defence Research Establishment Ottawa (DREO), and since 1994, at the Defence Research Establishment Suffield (DRES). Research efforts at these two establishments led to the successful completion of an engineering model for one size of such a protective glove. In order to advance the development of the new CB protective molded glove, detailed information on the sizes and shapes of hands of Canadian Forces (CF) personnel was needed. Thus, a requirement was identified for a comprehensive survey of CF hand anthropometry and simultaneous assessment of protective glove fit (*CF Glove Fit Study*) The findings from this study contributed in part to the finalization of a unique glove design developed as a sizeable computer aided design (CAD) model that incorporates over 40 hand dimensions from an anthropometric database of over 550 soldiers.

1.1 Objectives of the study

Five objectives were identified for the *CF Glove Fit Study*. These objectives are described below.

1. The first objective was to develop a database of hand/forearm dimensions for male and female CF personnel.

   A database of 63 hand/forearm dimensions was developed using traditional anthropometric measurement techniques on a sample of 536 CF personnel (178 females and 358 males)

2. The second objective was to evaluate the range and quality of fit provided by the five sizes of the in-service chemical warfare (CW) lightweight glove.

   Study participants were asked to select the best-fitting in-service CW glove size and to respond to a series of questions relating to the fit of the glove size chosen. This information was required to establish the acceptability of the in-service CW glove sizing system and to determine whether the current sizing system would be appropriate for the prototype CB glove

3. The third objective was to evaluate the range and quality of fit provided by the prototype CB protective glove.

   Study participants were asked to try on the prototype CB glove size and to respond to a series of questions relating to the fit of the glove. This information was used to determine the fit characteristics of the prototype glove. It was also used to describe the size of the prototype glove relative to the five sizes of the in-service CW glove

4. The fourth objective was to propose a sizing system for the new glove.

   The anthropometric data and glove fit data were used to develop a sizing system for the new CB glove.

5. The fifth objective was to develop design dimensions for the proposed sizing system.

   Design dimensions that reflect consideration of ease requirements within the glove as well as the use of a glove liner were developed for each glove size.

1.2 CF glove fit study reports

A great deal of information was collected and generated as part of the *CF Glove Fit Study*. As a result, this information is presented in a series of three reports. The first report is entitled: *Canadian Forces Glove Fit Study. Anthropometric Survey and Definition of Canadian Forces Hand Dimensions* [4]. The report presents the methodology employed to develop the database of hand dimensions. It also presents the methodology used to evaluate the range and quality of fit provided by the in-service CW glove and the prototype CB glove. Summary statistics for the hand dimensions that comprise the database are found in the first report

This second report is entitled: *Canadian Forces Glove Fit Study: Fit Assessment of In-Service Chemical Warfare Lightweight Glove and Molded Glove Prototype*, and presents the results from the glove fitting aspects of the study.

The third report is entitled: *Canadian Forces Glove Fit Study: Development of an Integrated Anthropometric Sizing System for Chemical Biological Protective Gloves* [5]. The report presents the steps taken to develop a sizing system for the prototype CB protective glove, along with the corresponding design dimensions for the glove sizes.

2. Methodology

This section provides a brief review of the glove fit assessment protocol. For a complete description of the methodology used in the *CF Glove Fit Study*, the reader is referred to the report on the study entitled: *Canadian Forces Glove Fit Study Anthropometric Survey and Definition of Canadian Forces Hand Dimensions* [4].

2.1 Glove fit assessment

Each participant in the study evaluated the fit of three protective glove systems. Information on the quality of glove fit was collected using questionnaires. In a previous study addressing functional fit and optimal ease requirements in gloves, an extensive questionnaire dealing with fit criteria was presented [2]. This was acceptable for a controlled study with 24 participants. Due to the large number of

participants involved in the *CF Glove Fit Study*, the questionnaires were based on the functional fit study but redesigned to focus only on the most critical fit areas. The aim was to develop a tool that would be very brief and simple to use, and yet gather enough information on glove fit to maximize the long-term usefulness and meaningfulness of the data. Three one-page questionnaires were developed for this purpose -- one questionnaire for each glove system. These questionnaires were available in French and English, they are presented in Annex A of this report.

2.1.1 Glove systems

The three different protective glove systems that were evaluated in the *CF Glove Fit Study* are described below. Photographs of the gloves are presented in Annex B.

1. The CF in-service CW lightweight glove (NATO Stock No. 8415-21-893-5210) was evaluated. This protective glove is made of vulcanized chloroprene and butyl rubber. It has a thickness of approximately 0.62 mm (24.5 mil). The in-service glove was available in five sizes -- extra-small, small, medium, large and extra-large.

2. The prototype molded CB protective glove (Mark 6G[1]) was evaluated. This glove is a symmetric, flat glove -- i.e., ambidextrous glove. It is made of bromobutyl rubber and has a thickness of approximately 0.76 mm (30 mil) Only one-size of this glove was available for evaluation.

3. The prototype molded CB protective glove (Mark 6G) was evaluated with a separate liner underlayer. The liner used with the protective glove is a developmental item that has demonstrated excellent fit characteristics in previous dexterity trials [7]. It is a highly stretchable knit liner made from a blend of cotton, viscose and Lycra. It has a relaxed thickness of approximately 1 mm (39 mil). The liner was available in four sizes -- small, medium, large and extra-large.

For the purposes of the fit assessment, the in-service glove was referred to as the *green glove* and the prototype glove as the *black glove*.

2.1.2 Glove fit assessment protocol

As participants entered the glove fit assessment phase of the study they were given a set of three questionnaires -- one for each glove system. They completed the assessment of the glove systems according to the order of the questionnaires in the set given to them. The questionnaires within each set were ordered such that possible effects on the fit responses attributable to the order of presentation of the glove systems were controlled. As there were three glove systems, six different orders of presentation were possible:

---

[1] For a more detailed description of this prototype glove refer to report entitled *Documentation of the Development of the New Concept Glove Design* [6].

1. in-service glove, prototype glove, prototype glove with liner;
2. in-service glove, prototype glove with liner, prototype glove;
3 prototype glove, in-service glove, prototype glove with liner;
4. prototype glove, prototype glove with liner, in-service glove;
5 prototype glove with liner, in-service glove, prototype glove; and
6. prototype glove with liner, prototype glove, in-service glove.

The questionnaire sets were dispensed to participants in a repeating cycle of the six orders described above. Instructions for completing the glove fit assessments were provided on each questionnaire Participants were also guided by one of the *CF Glove Fit Study* researchers whose main function was to supervise the fit assessment process. Specific details of the instructions given to each participant for the three glove systems are provided below

2.1.2.1 Fit assessment of in-service CW lightweight glove

For the in-service glove, the participant was instructed to select, from the five available sizes, the one that they felt fit them best. They were advised to select the glove size that they would be most comfortable wearing for approximately one-half day while performing a variety of tasks. The fit of the glove was only assessed on the right hand. Once the best-fitting size was selected, the participants were instructed as follows. "move your hand around for a short time with this glove size on -- clench and unclench your fist, spread your fingers out and in, and move your fingers up and down one by one. While you are still wearing the glove, please answer the following questions".

2.1.2.2 Fit assessment of unlined prototype CB protective glove

No glove size selection was required for the evaluation of the prototype glove. Each participant was instructed as follows: "Please try the black glove on your right hand There is only one size of this glove available so if you are not able to get this glove on, simply indicate this in your response to the first question below Move your hand around for a short time with this glove on -- clench and unclench your fist, spread your fingers out and in, and move your fingers up and down one by one. While you are still wearing the glove, please answer the following questions".

2.1.2.3 Fit assessment of lined prototype CB protective glove

For the evaluation of the prototype glove with the liner underlayer, the participant was first instructed to select the liner size that fit them best from the four available sizes. They were advised that the liner was designed to fit snugly and that the liner should fit well in the crotches of their hand and at the tips of their fingers. The fit of the

prototype glove with liner was only assessed on the right hand. Once the best-fitting liner size was selected the participants were instructed as follows: "Put the black glove on over the liner on your right hand. If you are unable to get this glove on over the liner, simply indicate this in your response to the first question below. Move your hand around for a short time with this glove on -- clench and unclench your fist, spread your fingers out and in, and move your fingers up and down one by one. While you are still wearing the liner and glove, please answer the following questions".

2.2 Study protocol

The protocol used to collect the hand dimension and glove fit data consisted of three distinct phases: briefing, hand measurement and fit assessment. These activities are described in *Canadian Forces Glove Fit Study· Anthropometric Survey and Definition of Canadian Forces Hand Dimensions* [5].

3. Results & discussion

This section presents results from the glove fit assessment portion of the *CF Glove Fit Study*. The reader is referred *Canadian Forces Glove Fit Study: Anthropometric Survey and Definition of Canadian Forces Hand Dimensions* [5], for information on the characteristics of the measured sample of CF personnel and summary statistics for the 63 dimensions that comprise the hand dimension database.

The glove fit assessment results are presented according to the questions that the study sought to solve. These questions are outlined below.

1. What percentage of the CF population is accommodated by the five-size system of the in-service CW lightweight glove?
2. What is the nature of glove fit with the in-service glove?
3. What percentage of the CF population is accommodated by the one-size of the prototype CB protective glove?
4. What is the nature of glove fit with the unlined prototype glove?
5. Where does the unlined prototype glove size lie within the five-size spectrum of the in-service glove?
6. What effect does the glove liner have on the fit of the prototype glove?

In order to address these questions, criteria were developed to define when the fit of the glove was considered acceptable based on the responses to the glove fit questionnaires. The criteria for acceptable glove fit are described in the following section.

3.1 Criteria for acceptable glove fit

Criteria for acceptable glove fit were required in order to. assess the sizing system for the in-service glove, describe the size of the prototype glove relative to the in-service glove, and describe the nature of fit provided by the three glove systems under investigation. Responses to two questions from the glove fit questionnaires provided the information needed to establish the criteria for acceptable glove fit. First, subjects were asked if they felt that the fit of the glove would allow them to perform most of their daily activities successfully. Only two response options were available for this question: "yes" and "no". Second, subjects were asked to rate the *overall fit* of the glove according to the following seven-point scale:

1	2	3	4	5	6	7
very good	good	somewhat good	neither good nor poor	somewhat poor	poor	very poor

The responses to these two questions were used to establish whether or not glove fit was acceptable for each subject. Glove fit was considered acceptable if an affirmative response, "yes", was received for the question regarding successful activity performance **and** if the overall glove fit was rated as equal to or better than "somewhat good" (i.e., ≤ "3") The rating used as the cut-off point for acceptable fit (i.e., "3") was somewhat arbitrary. The authors considered this value to be a *reasonable and realistic* goal for fit quality of CB protective gloves; and thus a "somewhat good" fit rating was regarded as an appropriate subjective fit performance standard for the in-service and prototype gloves. No objective performance measure, such as a dexterity test completion time, was collected as part of the *CF Glove Fit Study*. Therefore, the criteria for glove fit acceptability were based solely on the subjective responses. Different fit acceptability results may have been obtained if it had been possible to incorporate objective measures of glove fit into the criteria.

3.2 Evaluation of the in-service glove sizing system

One question that the glove fit assessments were designed to answer relates to the in-service glove sizing system and how effective this system is in accommodating the current CF population. The information needed to answer this question was obtained from the in-service glove size distributions for the male and female samples. Two types of distributions were of interest, gender specific distributions for the complete sample and gender specific distributions for the acceptable fit groups.

3.2.1 Size distributions for the in-service glove

The in-service CW lightweight glove was available in five sizes. As such, the first component of the in-service glove fit assessment involved selecting the best-fitting glove from the five available sizes. Subjects were instructed to select the size that they would feel most comfortable wearing for approximately one-half day, while performing a variety of tasks. Table 3-1 presents the results from the glove size selection activities for the in-service glove. It should be noted that the effectiveness of this self-selection sizing process was previously assessed for the in-service glove in a functional fit evaluation [2,6]. The results from the evaluation demonstrated that subjects were able to self-select, as a best fitting glove size, one that resulted in optimal performance in a battery of manual dexterity tests.

The information presented in Table 3-1 demonstrates that for the complete sample of male participants, the medium size in-service glove was selected more frequently than the other four sizes -- 39% of male participants chose the medium size as best fitting The male size distribution for the complete sample (i e , η=358) is normal in shape; it is depicted in the lightly shaded bars of Figure 3-1

In terms of the complete sample of female participants, the extra-small size was selected more frequently than the other four sizes. Seventy-two percent of female participants chose the extra-small size as best fitting. As such, the female size distribution for the complete sample (i.e., η=178), as depicted in the lightly shaded bars of Figure 3-2, is skewed to the right.

Using the criteria for acceptable glove fit, size distributions for the in-service glove were regenerated. The size distributions for the acceptable fit groups are presented in Table 3-1 (third column); they are also presented as the darker bars in Figure 3-1 and Figure 3-2. Only 78.2% of the complete male sample met the criteria for acceptable glove fit. An even smaller percentage, 69.7%, of the complete female sample met the criteria.

The acceptable fit distributions for both genders followed the same patterns as the complete sample distributions had followed. That is, the male acceptable fit group was normally distributed across the available glove sizes, with medium being the most popular size (37% of males within the acceptable fit group selected the medium sized glove). Similar to the complete female size distribution, the acceptable fit female group was considerably skewed, with the extra-small size being selected by 69% of females in this group.

Table 3-1. Size distributions for the in-service glove

Best-fitting Glove Size	Complete Sample		Acceptable Fit Group		% of Subjects in Acceptable Fit Group Out of Complete Sample
	No. of Subjects	% of Subjects	No. of Subjects	% of Subjects	
Males					
XS	31	9	26	9	7
S	74	21	67	24	19
M	140	39	103	37	29
L	80	22	62	22	17
XL	33	9	22	8	6
Sample size	*(η=358)*		*(η=280)*		78.2
Females					
XS	128	72	86	69	48
S	28	16	22	18	12
M	19	11	14	11	8
L	3	2	2	2	1
XL	0	0	0	0	0
Sample size	*(η=178)*		*(η=124)*		69.7

The size distributions for the acceptable fit groups demonstrate that a substantial number of subjects within each in-service glove size category did not meet the criteria for acceptable glove fit. The proportion of males within each size category that **did not** meet the acceptable fit criteria was as follows: 16% for the extra-small size, 9% for small, 26% for medium, 23% for large and 33% for extra-large. The proportion of females within each size that **did not** meet the acceptable fit criteria was as follows: 33% for the extra-small size, 21% for the small size, 26% for the medium size and 33% for the large size. Very few females comprise the medium- and large-size groups; therefore, the proportions for these sizes should be considered with this in mind. These results demonstrate that, in general, approximately one-quarter of all subjects within any given size category did not meet the criteria for acceptable fit with the in-service CW lightweight glove (except for the relatively high acceptability ratio demonstrated for males who chose the small size glove).

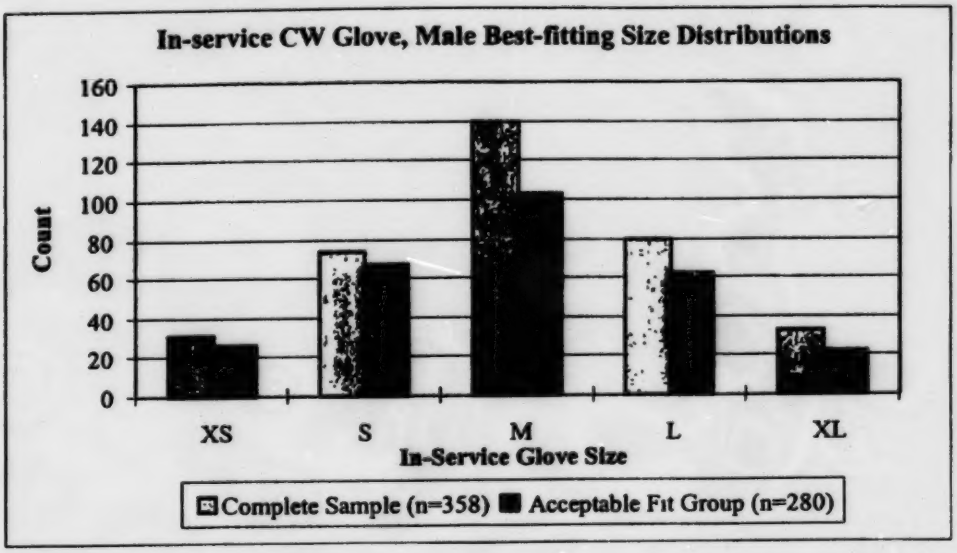


Figure 3-1. Male best-fitting size distributions for in-service glove – complete sample and acceptable fit group.

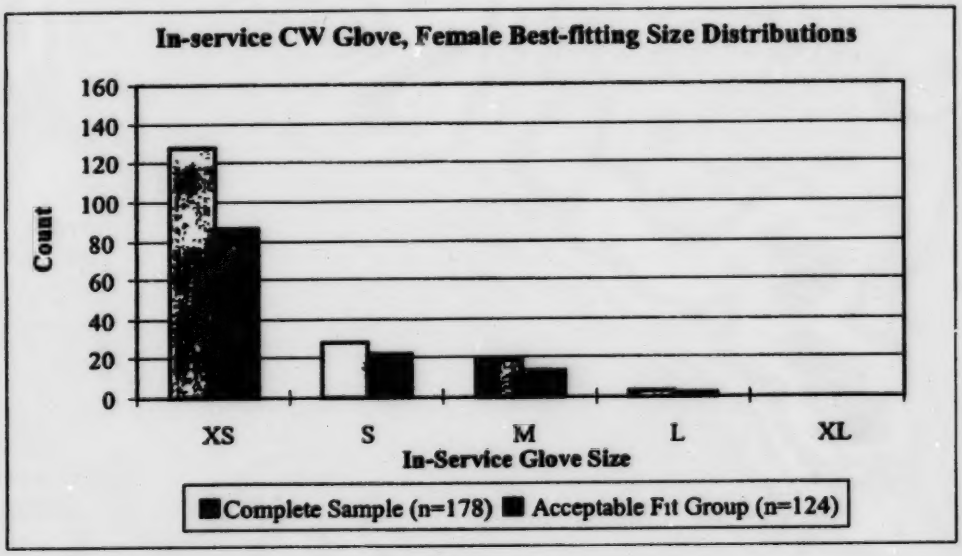


Figure 3-2. Female best-fitting size distributions for in-service glove – complete sample and acceptable fit group

In a perfect world, sizing systems for protective clothing would be developed such that 100% of the user population would be accommodated. This level of coverage, however, is usually very expensive and often an impossible task given the range and diversity of body dimensions, not to mention the complexities of design, manufacture, supply and distribution. A compromise is to develop sizing systems such that 90 to 95% of the user population can achieve an acceptable fit The in-service CW lightweight glove demonstrated 78% acceptable fit coverage of the male CF sample and 70% acceptable fit coverage of the female CF sample. Assuming that the measured sample is representative of the total CF, these results indicate that there are a number of personnel who would not obtain an acceptable fit with the current sizing system. Considering the female data, the in-service sizing system obviously lacks coverage for small female hands. The male data indicate that the sizing system is failing at the larger sizes: medium, large and extra-large.

The nature of fit for the in-service glove is examined in the following section in order to establish the strengths and weaknesses of the in-service CW glove sizing system.

3.2.2 Nature of in-service glove fit

The nature of fit provided by the in-service CW lightweight glove is assessed in this section by examining the overall fit ratings as well as area-specific glove fit problems.

3.2.2.1 Overall fit ratings for the in-service glove

Subjects were asked to rate the overall fit of the glove by circling the number, on the following seven-point scale, that corresponded to the most appropriate description of overall glove fit for them

1	2	3	4	5	6	7
very good	good	somewhat good	neither good nor poor	somewhat poor	poor	very poor

Mean overall fit ratings for each in-service glove size are presented in Table 3-2. The mean ratings for the complete male sample range from 2.06 (~"good") for the extra-small size, to 3.03 (~"somewhat good") for the extra-large size with an average of 2.63 for all sizes. As expected, when only those subjects whose responses met the acceptable fit criteria were considered, the mean overall fit ratings were lower (i.e., closer to "very good") than those of the complete sample. The ratings from the male acceptable fit group ranged from 1.81 for the extra-small size to 2.44 for the medium size in-service glove, with an average rating of 2.27 for all sizes. In terms of the total female sample, the mean overall fit ratings ranged from 2.64 for the small size to 4.00 for the large size, with an average of rating of 2.99 for all sizes. Again, as expected, the mean ratings for the female acceptable fit group were lower; they ranged from 2.22 for the extra-small size to 3.00 for the large size in-service glove, with an average rating of 2.29 for all sizes.

These mean overall fit ratings reveal that the extra-small and small sizes generally received better ratings than the medium, large and extra-large glove sizes. This was true for both the male acceptable fit group as well as the complete male sample. These results parallel earlier observations that greater proportions of the male subjects who chose the extra-small and small glove sizes met the criteria for acceptable glove fit.

Gender differences in the overall fit ratings were apparent. The size-specific overall fit ratings for the complete female sample were notably higher, i.e., closer to the "very poor" extreme, than those of the complete male sample. However, the overall fit ratings for the genders were quite similar when only the acceptable fit groups were considered (mean male rating of 2.27 and mean female rating of 2.29). On the other hand, when acceptable fit criteria were not met, the overall fit ratings were quite different between the two genders -- the females rated the overall fit closer to the "very poor" extreme than the males (mean male rating of 4.26 and mean female rating of 4.61).

Three general conclusions can be drawn from the overall fit ratings for the in-service CW lightweight glove.

1. For male CF personnel, the extra-small and small in-service glove sizes provided better fit than the three larger sizes.

2 When acceptable fit criteria were met, the mean overall fit ratings were comparable between the genders.

3. When acceptable fit criteria were **not** met, the female subjects rated the overall fit of the in-service glove considerably poorer than the male subjects had.

Table 3-2. Mean overall fit ratings for the in-service glove

	Best-fitting In-service Glove Size					All Sizes
	XS	S	M	L	XL	
Males – Complete Sample						
Mean	2 06	2 35	2 89	2 83	3 03	2 63
SD	0 96	0 85	0 98	1 25	1 40	1 10
η	31	74	140	80	33	358
Males – Acceptable Fit Group						
Mean	1 81	2 16	2 44	2 29	2.32	2 27
SD	0 75	0 54	0 54	0 66	0.72	0 63
η	26	67	103	62	22	280
Males – Unacceptable Fit Group						
Mean	3 40	4 14	4 14	4 67	4 45	4 26
SD	0 89	1 21	0 86	1 03	1 37	1 04
η	5	7	37	18	11	78
Females – Complete Sample						
Mean	3 02	2 64	3 16	4 00	-	2 99
SD	1 38	1 22	1 07	1 73	-	1 33
η	128	28	19	3	-	178
Females – Acceptable Fit Group						
Mean	2 22	2 23	2 71	3 00	-	2 29
SD	0 62	0 75	0 61	0 00	-	0 66
η	86	22	14	2	-	124
Females – Unacceptable Fit Group						
Mean	4 67	4 17	4 40	6 0	-	4 61
SD	0 98	1.47	1 14	-	-	1.05
η	42	6	5	1	-	54

Note: Overall glove fit was based on a seven-point scale where "very good" overall fit was equated to "1" and "very poor" fit was equated to "7".

3.2.2.2 Fit problem areas for the in-service glove

In the third element of the glove fit assessment, participants were asked to identify specific fit problem areas with the in-service glove size they had chosen as best-fitting and to qualify each fit problem identified. Seven potential glove fit problem areas were listed on the questionnaires: finger length, finger girth, palm length, palm girth, wrist girth, cuff length, and cuff girth. Participants were asked to indicate whether the glove fit was "a lot too short", "a little too short", "a little too long" or "a lot too long" for each glove ***length*** area that they considered problematic in terms of fit. They were also asked to indicate whether the glove fit was "a lot too tight", "a little too tight", "a little too loose" or "a lot too loose" for each glove ***girth*** area that they considered problematic in terms of fit. Figure 3-3 presents the response format that was used for fit problem identification and qualification.

For analysis purposes, the area-specific fit problem responses were numerically coded such that: "a lot too short/tight" responses were coded as "1", "a little too short/tight" responses were coded as "2", null responses were coded as "3" and interpreted as indicating no fit problem for the area in question, "a little too long/loose" responses were coded as "4", and "a lot too long/loose" responses were coded as "5". The researcher responsible for the glove fit assessments confirmed null responses as indicating a lack of fit problem.

Please check off any fitting problems you have with this glove size (check all that apply)

TOO SMALL			TOO LARGE		
	a little	a lot		a little	a lot
glove fingers too short			glove fingers too long		
glove fingers too tight			glove fingers too loose		
glove palm too short			glove palm too long		
glove palm too tight			glove palm too loose		
glove wrist too tight			glove wrist too loose		
glove cuff too short			glove cuff too long		
glove cuff too tight			glove cuff too loose		

Figure 3-3. Response format for fit problem area identification and qualification.

3.2.2.2.1. Fit problems for male subjects

Figure 3-4 presents the frequencies of specific fit problem area responses for the male acceptable fit group. This figure only presents data for those subjects whose responses met the criteria for acceptable glove fit, yet fit problems were frequently reported in finger length and palm girth. Over 50% of subjects in the acceptable fit group reported finger length fit problems, and almost 40% reported palm girth fit problems. For both of these dimensions, the majority of the fit problems were on the "long"/"loose" end of the response spectrum. Only 20% of male subjects in the acceptable fit group indicated that wrist girth was a fit problem; yet, almost all of these subjects felt the wrist girth was "too loose". For the other dimensions (i.e., finger girth, palm length, cuff length and cuff girth), problematic responses were infrequent and those received were evenly split between the "too short"/"too tight" and "too long/"too loose" options. Based on these results, it appears that the size of the in-service glove in these four areas was appropriate -- the glove dimensions appear well centered

Figure 3-5 summarizes the fit problem area responses for all those men who ***did not*** meet the acceptable fit criteria. As expected, a relatively larger percentage of subjects in this group reported fit problem areas compared to the acceptable fit group. In addition, for all fit problem areas, except cuff girth, the vast majority of ratings were on the "long"/"loose" end of the response spectrum. In terms of cuff girth, the responses were evenly split between the "too tight" and "too loose" options The results from the unacceptable fit group indicate that when a subject could not achieve acceptable fit with one of the five in-service glove sizes they chose a glove size that fit somewhat larger instead of one that provided a somewhat smaller fit.

The response frequencies for the glove fit problem areas presented in Figure 3-4 and Figure 3-5 are general to all five glove sizes. In order to gain greater insight into whether or not the fit problem areas of the in-service glove were general, or specific to certain glove sizes, the area-specific fit problem responses were compared across the best-fitting in-service glove sizes. Table 3-3 presents the mean fit problem area responses for both the acceptable fit and unacceptable fit male groups.

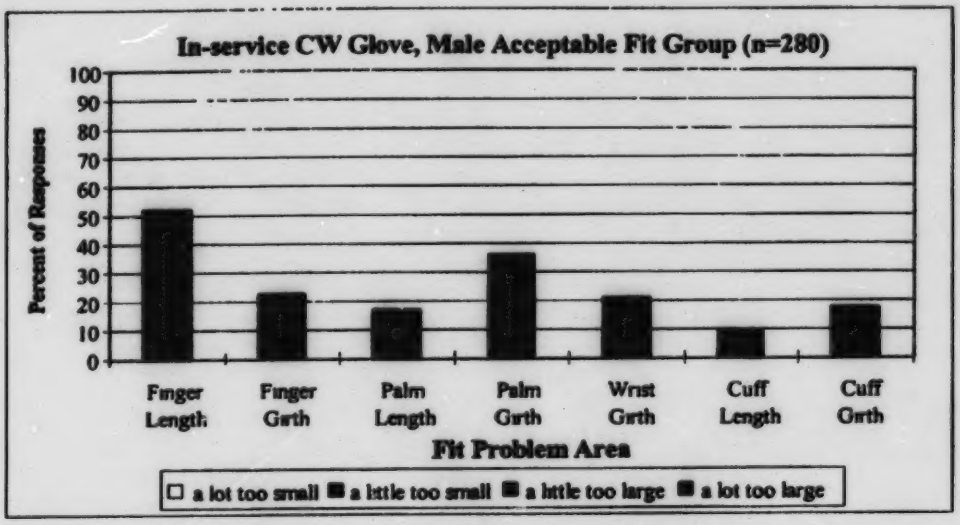


Figure 3-4. Frequency of area specific fit problems for male subjects within the in-service CW glove acceptable fit group, all sizes considered.

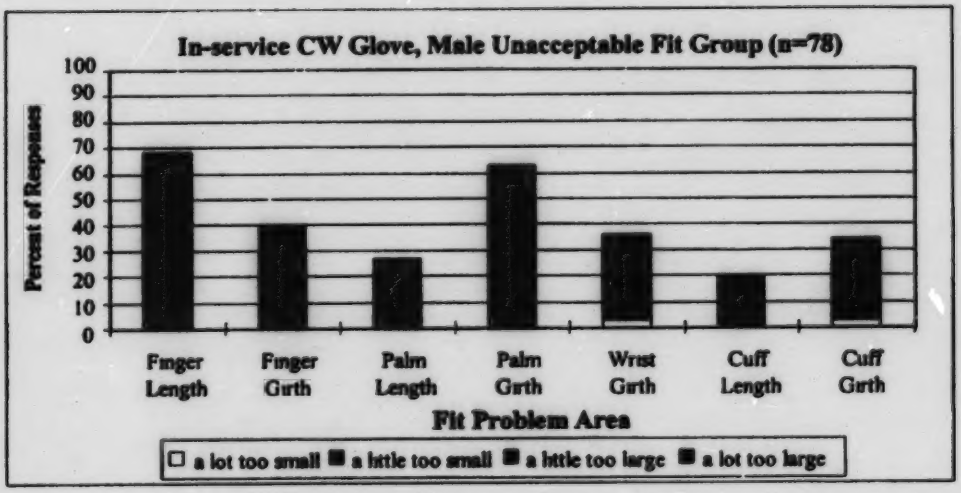


Figure 3-5. Frequency of area specific fit problems for male subjects within the in-service CW glove unacceptable fit group, all sizes considered

Table 3-3. Mean male fit problem area ratings for the in-service CW glove

Problem Area	Best-fitting In-service Glove Size				
	XS	S	M	L	XL
Males	**Acceptable Fit Group**				
Finger length †	2.81$_a$	3.00$_{a,c}$	3.37$_b$	3.47$_b$	3.41$_{b,c}$
Finger girth	2.92	2.94	3.03	3.08	3.05
Palm length †	2.81$_a$	2.90$_a$	3.10$_b$	3.03$_{a,b}$	3.00$_{a,b}$
Palm girth	3.19	3.27	3.45	3.23	3.41
Wrist girth	3.15	3.25	3.22	3.05	3.14
Cuff length	2.85	2.97	3.07	3.06	2.95
Cuff girth †	3.19$_b$	3.09$_{a,b}$	2.92$_{a,b}$	2.87$_a$	3.09$_{a,b}$
Sample size (n)	*26*	*67*	*103*	*62*	*22*
Males	**Unacceptable Fit Group**				
Finger length	3.40	3.29	3.46	3.61	4.27
Finger girth	3.40	3.29	3.35	3.22	3.27
Palm length	3.60	3.43	3.16	2.94	3.18
Palm girth	3.40	3.86	3.86	3.44	3.64
Wrist girth	3.40	3.43	3.35	3.00	3.27
Cuff length	3.00	3.57	3.11	2.94	3.09
Cuff girth	3.40	3.43	2.84	2.83	2.91
Sample size (n)	*5*	*7*	*37*	*18*	*11*

Note: Fit problem area responses coded as "a lot too short/tight" = "1", "a little too short/tight" = "2", no reported fit problem = "3", "a little too long/loose" = "4", and "a lot too long/loose" = "5"

Note: Means with the same subscript letter are not significantly different ($\alpha = .05$)

† Significant effect of glove size on fit rating ($\alpha = .05$)

The top half of Table 3-3 presents the mean fit ratings for the acceptable fit male group. One-way General Linear Models Analyses of Variance (GLM ANOVAs) were completed for each fit problem area, with the fit rating as the dependent variable and glove size as the independent variable. The results from these ANOVAs indicated that glove size had a significant effect on the fit ratings for finger length, palm length and cuff girth dimensions (α=.05). The results of Tukey's HSD multiple comparison tests for these fit problem areas are included in Table 3-3 (i.e., means with the same subscript letter are not significantly different).

A number of conclusions can be drawn from the data presented in the top half of Table 3-3

- First, the glove fingers were rated as somewhat long by men who chose the medium, large and extra-large sizes as best-fitting, compared to the ratings for the extra-small and small sizes which were fairly close to the optimal rating of "3".
- Second, palm length ratings were significantly lower for the extra-small and small size gloves than for the medium size glove. However, the mean ratings for all sizes encompassed the optimal rating of "3" fairly well.
- Third, cuff girth was rated as somewhat smaller for the large size glove (slightly tight) than for the extra-small glove (slightly loose). However, the mean ratings for all sizes encompassed the optimal rating of "3" fairly well.
- Fourth, glove finger girth, wrist girth and cuff length ratings, for all glove sizes, fell reasonably close to the optimal rating of "3".
- Fifth, palm girth was rated as somewhat loose for all glove sizes.

In summary, the most significant size specific fit problem, with the in-service CW glove, apparent for the acceptable fit male group, was the excessive finger lengths for the medium, large and extra-large sizes. Excessive palm girth was also reported, but this was a problem for all glove sizes.

The size-specific mean fit problem ratings for the acceptable fit male group deviate considerably from those generated for the unacceptable fit group. The ratings for the unacceptable fit group are presented in the bottom portion of Table 3-3. GLM ANOVAs were not completed for the unacceptable fit group to determine the effect of glove size on the ratings because of the small cell sizes for the extra-small, small and extra-large glove sizes However, as can be seen from the mean ratings, finger length, finger girth, palm length, palm girth and wrist girth were consistently rated on the "long"/"loose" end of the response spectrum for all sizes, with only one exception -- large size glove, palm length, rated ~"3". The extra-small and small sizes were rated as somewhat loose in cuff girth, while the cuff girth ratings were fairly close to optimal for the other sizes. Cuff length appears to have been excessive only for the small glove. In summary, with only a few exceptions, "long"/"loose" fit problems were experienced by the unacceptable fit male group for all sizes in most glove dimensions, especially finger length and palm girth.

3.2.2.2.2. Fit problems for female personnel

Figure 3-6 presents the frequencies of specific fit problem area responses for the female acceptable fit group. This figure demonstrates that fit problems were frequently reported in finger length, finger girth, palm girth and wrist girth. The vast majority of fit problems for these dimensions were on the "long"/"loose" end of the response spectrum. For the other dimensions, (i.e., palm length, cuff length and cuff girth) problematic responses were not as frequent, but again they were consistently on

the "long"/"loose" end of the response spectrum. Therefore, even though responses from the subjects within this group met the criteria for acceptable glove fit, numerous reports of the glove fit being too large were received.

Figure 3-7 summarizes the fit problem area responses for all those women who ***did not*** meet the acceptable fit criteria Fit problems in five areas -- finger length, finger girth, palm girth, wrist girth and cuff girth -- were reported by at least 70% of subjects in this group Virtually all of the problems were with the glove fitting "too long"/"too loose" in these dimensions.

Table 3-4 presents the mean fit problem area responses across the glove sizes for the female data. The top half of this table presents the means for the acceptable fit female group. The numbers of females within the medium and large glove sizes were quite small for this group Thus, statistical examination of the size specific means was not appropriate. However, review of the mean ratings, for the female acceptable fit group, led to the following three conclusions.

- The fit problem ratings for the extra-small size were on the "long"/"loose" end of the response spectrum for all dimensions except cuff length, which was close to "3" (i.e., "no reported fit problem").

- The mean ratings for the small size glove were reasonably close to "3" (i.e., "no reported fit problem") for all but two fit areas -- palm girth and wrist girth, which were rated on the "loose" end of the response spectrum.

- The medium size mean fit ratings were reasonably close to "3" (i.e., "no reported fit problem") for all dimensions except finger length, palm girth and wrist girth. Note that the cell size for the large size category of the acceptable fit female group was too small for interpretation.

In summary, females who chose the extra-small glove size as best-fitting, and whose responses met the criteria for acceptable glove fit, often found this size "too long"/"too loose" in many dimensions. Similar problems were apparent for the small and medium glove sizes of the acceptable fit group, but only for the palm girth, wrist girth and, to some extent, finger length dimensions.

Examination of the mean fit problem ratings for the unacceptable fit female group (bottom portion of Table 3-4) reveals that the mean ratings for the extra-small size were "long"/"loose" in all fit areas except cuff length. The greatest excesses were apparent for the extra-small glove size in finger length, finger girth, palm girth and wrist girth dimensions. The numbers of females in the small, medium and large glove size categories of the unacceptable fit group were too small to allow meaningful comparison of the mean ratings.

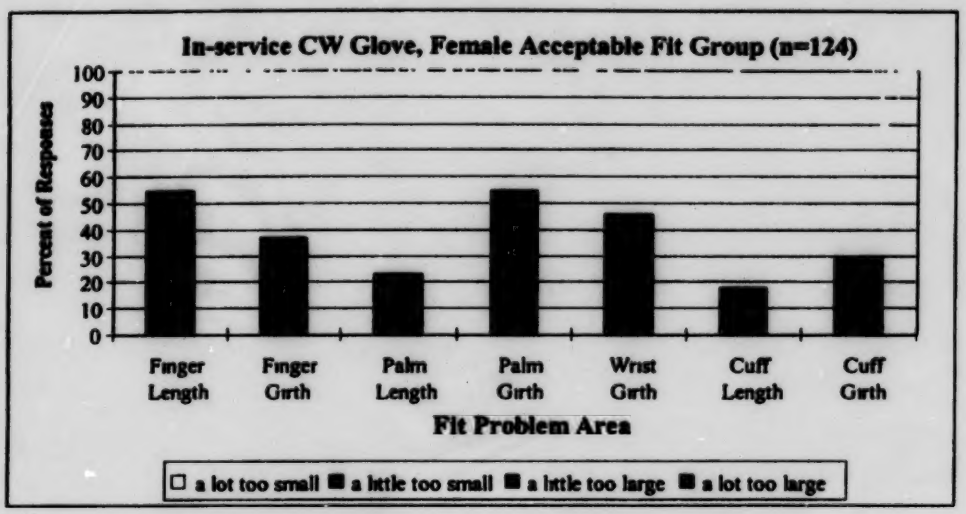


Figure 3-6. Frequency of area specific fit problems for female subjects within the in-service CW glove acceptable fit group, all sizes considered.

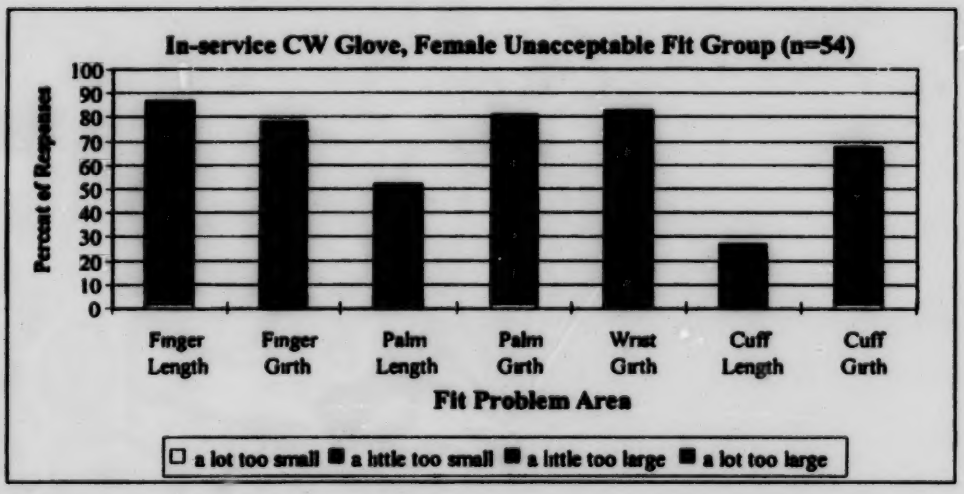


Figure 3-7. Frequency of area specific fit problems for female subjects within the in-service CW glove unacceptable fit group, all sizes considered

Table 3-4. Mean female fit problem area ratings for the in-service CW glove

Problem Area	Best-fitting In-service Glove Size				
	XS	S	M	L	XL
Females	**Acceptable Fit Group**				
Finger Length	3 37	3 09	3 36	3 00	-
Finger Girth	3 49	3 18	3 29	3 00	-
Palm Length	3 24	3 00	3 14	3 00	-
Palm Girth	3 69	3 55	3 64	4 00	-
Wrist Girth	3 58	3 50	3 43	4.00	-
Cuff Length	3 09	3 14	3 21	3 00	-
Cuff Girth	3 33	3 23	3 21	3.00	-
Sample size (n)	*86*	*22*	*14*	*2*	-
Females	**Unacceptable Fit Group**				
Finger Length	4 00	3 33	3 40	2 00	-
Finger Girth	4 12	3.83	3 60	5 00	-
Palm Length	3 60	3 83	3 40	3 00	-
Palm Girth	4 12	3 83	4.20	4 00	-
Wrist Girth	4 24	4 00	4 00	3 00	-
Cuff Length	3 36	3.33	3 40	3 00	-
Cuff Girth	3 71	3 83	3 20	3.00	-
Sample size (n)	*42*	*6*	*5*	*1*	-

Note Fit problem area responses coded as: "a lot too short/tight" = "1", "a little too short/tight" = "2", no reported fit problem = "3", "a little too long/loose" = "4", and "a lot too long/loose" = "5"

In summary, the female CF personnel who participated in the CF Glove Fit Study had obvious problems with the "long"/"loose" fit of the in-service glove in many areas of the hand. This was clearly evident for the unacceptable fit and acceptable fit groups. Only responses from females who had selected the small size glove as best fitting, in the acceptable fit group, were reasonably close to the optimal rating of "3" for most fit areas except palm girth and wrist girth. Males in the acceptable fit group for the small size glove also identified these two areas as being "too loose".

3.2.2.3 Nature of in-service glove fit – Conclusions

The in-service CW lightweight protective glove provided a reasonably good fit for those men whose responses met the criteria for acceptable glove fit. Two exceptions, however, were noted. First, that the glove finger lengths were considered somewhat long by men wearing the medium, large and extra-large sizes. The problem with excessive finger length for these glove sizes provides some explanation for the higher proportion of men at these sizes, compared to the extra-small and small sizes, who did not meet the criteria for acceptable glove fit. The second exception was that palm

girth was considered somewhat loose for all glove sizes. The men whose responses did not meet the criteria for acceptable glove fit consistently reported problems with the "long"/"loose" fit of the glove in a number of areas.

The in-service glove provided a reasonably good fit for women who chose the small glove size as best fitting and whose responses met the criteria for acceptable glove fit. Two exceptions were noted -- these women rated palm and wrist girths as somewhat "loose". In general, women in the acceptable fit group who chose the extra-small glove size as best fitting considered the in-service glove too large in all dimensions, except cuff length. Similarly, when the acceptable fit criteria were not met, the fit problem ratings indicated that the gloves were too large in all dimensions.

Gender differences were quite obvious for the responses that characterized the nature of fit provided by the in-service glove. The average overall fit ratings were worse for the female sample. In addition, the female sample demonstrated much higher frequencies of fit problems and they reported fit problems of a greater magnitude than the male sample. These results are not surprising as 72% of the complete female sample selected the smallest available glove size as the one that fit them best from the five sizes -- their size options were obviously very limited.

The following section, Section 3.3, addresses fitting aspects of the unlined prototype CB protective glove.

3.3 Evaluation of the unlined prototype glove

As part of the *CF Glove Fit Study* a fit evaluation was also completed for the unlined prototype CB protective glove. Only one size of the prototype glove was available for evaluation. The fit of the unlined prototype glove was evaluated in order to:

- identify the range of fit provided by the available size,
- describe the nature of fit provided by the glove,
- describe the hand sizes that achieved acceptable fit with the glove, and
- determine where the glove size lies within the five-size spectrum of the in-service CW lightweight glove.

The questionnaire used to evaluate the fit of the unlined prototype glove was identical to that used for the in-service glove fit evaluation, excluding the size selection components.

3.3.1 Range of unlined prototype glove fit

In order to establish the percentages of the male and female CF study samples that were accommodated by the one-size of the prototype glove, the acceptable fit criteria were employed (refer to Section 3.1, "Criteria for Acceptable Glove Fit"). The

questionnaire responses for the unlined prototype glove revealed that 56.4% of male subjects met the criteria for acceptable glove fit, and 21.3% of female subjects did. It is quite surprising that acceptable fit criteria were met by 56.4% of male subjects for the prototype glove size; this compares to 28.8% for the medium size in-service glove -- the medium size had the highest tariff for the male acceptable fit group (refer to Table 3-1).

3.3.2 Nature of fit for the unlined prototype glove

The nature of fit for the unlined prototype glove was assessed by examining the overall fit rating responses as well as fit problems specific to certain areas of the glove.

3.3.2.1 Overall fit ratings for the unlined prototype glove

Table 3-5 presents mean overall fit ratings for the unlined prototype glove. Mean ratings are presented for both genders for the acceptable fit and unacceptable fit groups. In addition, mean ratings for the in-service glove are included for comparison purposes.

In terms of the unlined prototype glove, the mean overall fit ratings, for both the male and female *acceptable* fit groups are approximately mid-way between the "good" ("2") and "somewhat good" ("3") fit qualifiers (mean ratings of 2.45 and 2.61, respectively). Considering only the *acceptable* fit groups, the mean overall fit ratings for the unlined prototype glove were quite similar to those of the in-service glove, especially for the male sample (mean overall fit ratings of 2.45 versus 2.27, respectively, for the males, and 2.61 versus 2.29, respectively, for the females). When only the *unacceptable* fit groups are considered, the mean overall fit ratings for the unlined prototype gloves were notably higher (i.e., closer to the "very poor" fit qualifier) than those of the in-service glove -- especially for the female sample. With only one glove size available, it was expected that the *unacceptable* fit group would rate the overall fit of the unlined prototype glove notably poorer than the in-service glove had been rated.

Table 3-5. Mean overall fit ratings for unlined prototype and in-service gloves

	Unlined Prototype Glove		In-service Glove -- All Sizes	
	Acceptable Fit Group	Unacceptable Fit Group	Acceptable Fit Group	Unacceptable Fit Group
Males				
Mean	2.45	4.63	2.27	4.26
SD	0.61	1.10	0.63	1.04
n	202	156	280	78
Females				
Mean	2.61	5.81	2.29	4.61
SD	0.55	1.07	0.66	1.05
n	38	140	124	54

Note: Overall glove fit was based on a seven-point scale where "very good" overall fit was equated to "1" and "very poor" fit was equated to "7"

3.3.2.2 Fit problem areas for the unlined prototype glove

Subjects were asked to identify fit problem areas on the unlined prototype glove, as they had been asked to do for the in-service glove. The fit problem area responses for the unlined prototype glove are described in the following sections.

3.3.2.2.1. Fit problems for male subjects

Figure 3-8 presents the frequencies of fit problem area responses for the male *acceptable* fit group. This group reported a relatively high number of fit problems in finger length (50.6% of responses were problematic) and in palm girth (46.1% of responses were problematic). Problematic responses were received from less than 30% of men in this group for the other glove fit areas, namely, finger girth, palm length, wrist girth, cuff length and cuff girth. When fit problems were reported they were mainly on the "long"/"loose" extreme, with the exception of palm length, where the responses were evenly spread between the "short" fit and the "long" fit response extremes.

As expected, when acceptable fit criteria were not met for the unlined prototype glove there was a considerably higher frequency of fit problem responses for all glove areas, in comparison with the acceptable fit group (see Figure 3-9). Finger length fit and palm girth fit were noted as problematic by over 70% of men in this group. Finger girth was a fit problem area for over 60% of men in the unacceptable fit group. There was a clear majority of fit problem responses on the "long"/"loose" extreme for this group, with two exceptions. These exceptions were palm length and cuff length -- both of these areas received responses that were evenly spread between the "short" fit and "long" fit extremes. Despite the clear majority of "long"/"loose" fit problems, there was still reasonable representation from the "short"/"tight" response extreme for all fit problem areas except cuff girth, which is weighted very heavily with responses on the "loose" extreme. Thus, of the 44% of male subjects who did not meet acceptable fit criteria with the unlined prototype glove, the glove was not large enough for approximately one-third of them in certain dimensions (finger length, finger girth, palm length, palm girth and wrist girth), and it was too large for the remainder especially in finger length, finger girth and palm girth.

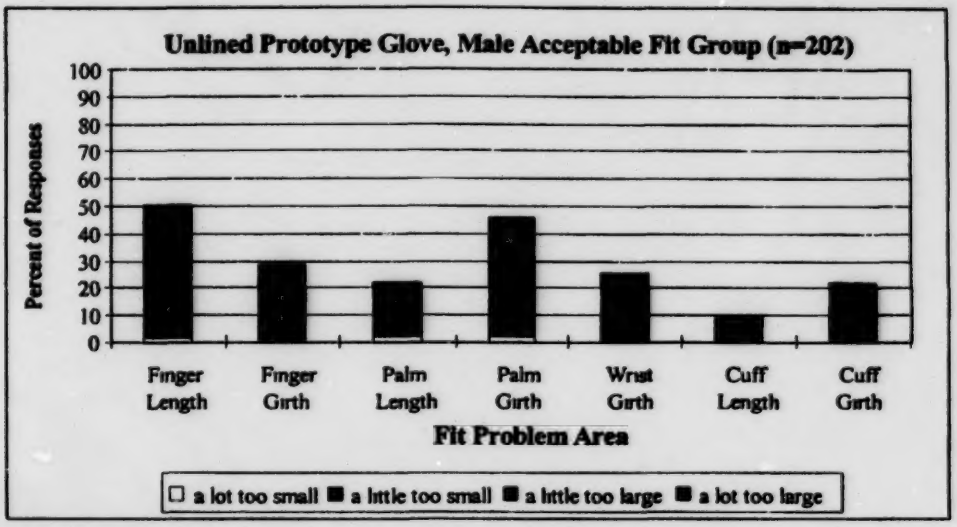


Figure 3-8. Frequency of area specific fit problems for male subjects within the unlined prototype glove acceptable fit group.

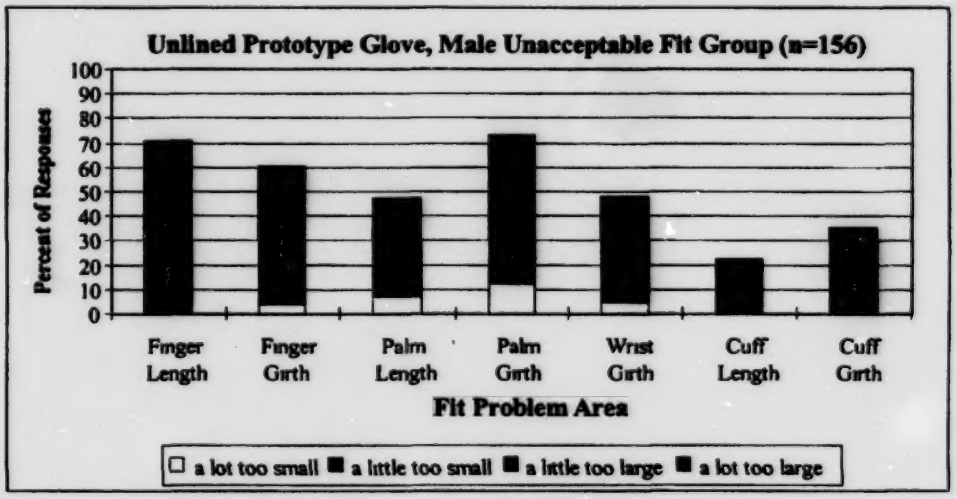


Figure 3-9. Frequency of area specific fit problems for male subjects within the unlined prototype glove unacceptable fit group.

In summary, when acceptable fit criteria were met for the unlined prototype glove, the following fit problems were evident for the male subjects: somewhat "long" fit of glove fingers, somewhat "loose" fit of glove palm, and "loose" fit in cuff girth. The results from the unacceptable fit group revealed that the prototype glove size is a reasonably large size of glove, as there was a clear majority of "long"/"loose" fit problems reported, compared to "short"/"tight" fit problems.

Mean fit problem ratings were calculated for the unlined prototype glove, using the same method that was employed for the in-service glove. Ratings for the acceptable and unacceptable fit groups for both genders are presented in Table 3-6. The mean fit problem area ratings were very similar for the unlined prototype glove and in-service glove, for the male acceptable fit groups. The fact that fit problems were no more pronounced for the prototype glove than for the in-service glove provides validation for the high acceptable fit rate of 56% observed for male subjects with the unlined prototype glove.

3.3.2.2.2. Fit problems for female subjects

The graphs of fit problem area response frequencies for the females demonstrate a much higher frequency of problematic responses, both for the acceptable fit group (Figure 3-10) and the unacceptable fit group (Figure 3-11). The highest frequencies of problematic responses were received for the fit of the glove in finger length, finger girth, palm girth and wrist girth. This was evident for both the acceptable and unacceptable fit groups. Virtually all fit problem responses for all areas of the glove were rated as "long"/"loose". High percentages of "a lot too long" and "a lot too loose" responses were received for the unacceptable fit group. Therefore, although a small percentage of females in the acceptable fit group found the prototype glove finger and palm length "too short", most women found the glove too "long"/"loose". A large percentage of women did not meet acceptable fit criteria for this glove -- 79%. The glove fit was "a lot too long" and "a lot too loose" in most areas for virtually all of these women.

Mean fit problem area ratings for the female groups are presented in the bottom half of Table 3-6. The ratings for the unlined prototype glove acceptable fit group deviate considerably from the optimal rating of "3" (i.e., "no reported fit problem"). Therefore, even though the acceptable fit criteria were met for 21% of the female sample, significant fit problems were reported by this group with the unlined prototype glove.

Table 3-6. Mean fit problem area ratings for unlined prototype and in-service gloves

Fit Problem Area	Unlined Prototype Glove		In-service Glove – All Sizes	
	Acceptable Fit Group	Unacceptable Fit Group	Acceptable Fit Group	Unacceptable Fit Group
Males				
Finger Length	3.28	3 62	3 25	3 59
Finger Girth	3 18	3 47	3 01	3.31
Palm Length	3.01	3 12	3 00	3.18
Palm Girth	3 20	3 28	3 33	3 71
Wrist Girth	3.20	3 20	3 18	3.27
Cuff Length	3 07	3 10	3 01	3 10
Cuff Girth	3 27	3 37	2.99	2 94
η	202	156	280	78
Females				
Finger Length	3.97	4 68	3 31	3 83
Finger Girth	4 16	4 56	3 40	4 06
Palm Length	3.45	4.11	3 19	3.59
Palm Girth	4.03	4 60	3 66	4.09
Wrist Girth	3 87	4 50	3 56	4.17
Cuff Length	3 34	3 77	3 11	3 35
Cuff Girth	3 76	4 29	3 29	3 67
η	38	140	124	54

Note. Fit problem area responses coded as "a lot too short/tight" = "1", "a little too short/tight" = "2", no reported fit problem = "3", "a little too long/loose" = "4", and "a lot too long/loose" = "5"

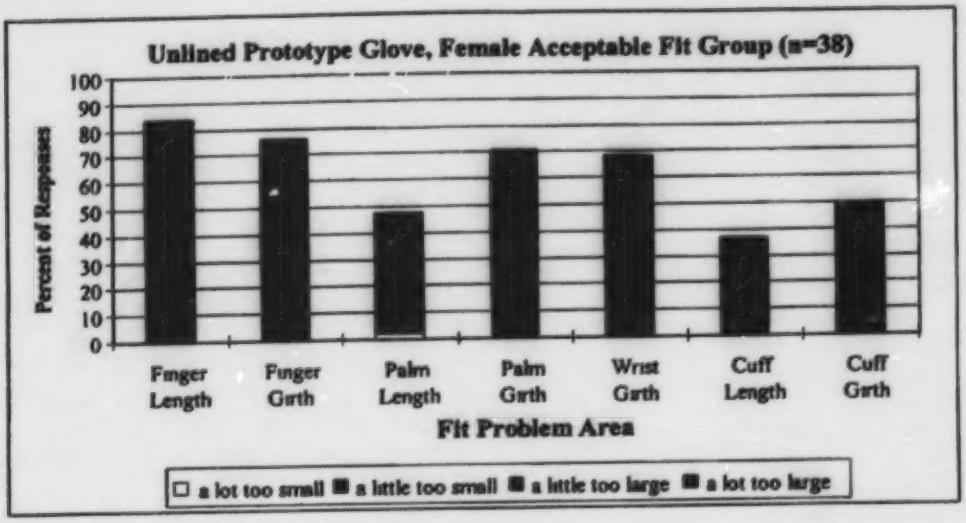


Figure 3-10. Frequency of area specific fit problems for female subjects within the unlined prototype glove acceptable fit group.

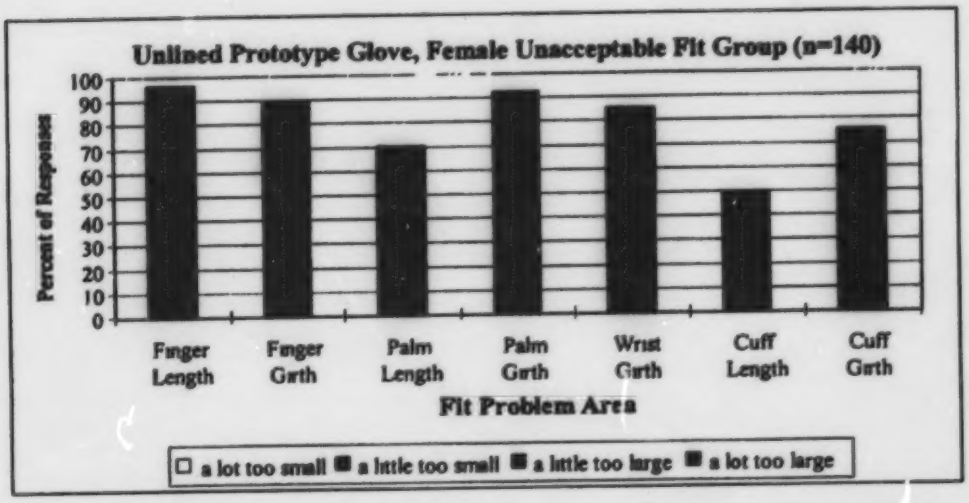


Figure 3-11. Frequency of area specific fit problems for female subjects within the unlined prototype glove unacceptable fit group.

3.3.2.2.3. Nature of unlined prototype glove fit – conclusions

The unlined prototype glove provided a reasonably good fit for those men whose questionnaire responses met the criteria for acceptable glove fit. However, as with the in-service CW glove, the men in this group did experience some fit problems. Glove finger length was rated as somewhat "long"; and glove palm girth, finger girth and cuff girth were considered somewhat "loose".

The unlined prototype glove provided a poor fit for women. This was evident in the small number of women whose responses met the criteria for acceptable glove fit (21%) and it was evident in the relatively high (i.e., closer to "very poor" fit qualifier) mean overall fit ratings. It was also evident in the high frequency of fit problem areas reported for the glove. The unlined prototype glove was too large for almost all female participants across all glove dimensions.

3.3.3 Location of prototype glove size relative to in-service CW glove sizes

In order to determine where the prototype glove size lies within the spectrum of the in-service CW lightweight glove sizes, size distributions for the in-service glove were generated using those subjects whose responses met the criteria for acceptable glove fit for the prototype glove. The information presented in Table 3-7 demonstrates that 35% of male subjects who chose the extra-small in-service glove as best-fitting provided responses for the unlined prototype glove fit evaluation that met the criteria for acceptable glove fit Similarly, 45% of male subjects who chose the small, 61% of male subjects who chose the medium, 70% of male subjects who chose the large and 48% of male subjects who chose the extra-large size in-service glove provided responses for the unlined prototype glove that met the acceptable fit criteria. According to these results from the male sample, the unlined prototype glove size appears to be similar to the medium and large in-service CW lightweight glove sizes The female responses cannot be assessed in this context because only 21% of the females involved in the study comprised the acceptable fit group for the unlined prototype glove and the fit problem area responses for these women revealed that they found the glove "too long"/"too loose" in most dimensions.

Another way to approach the question of where the prototype glove size falls within the spectrum of the in-service glove sizes, is to examine the hand dimensions of those subjects who achieved acceptable fit with the in-service glove and compare them to those of subjects who achieved acceptable fit with the unlined prototype glove. This approach is addressed in the following section.

Table 3-7. Distribution for acceptable fit unlined prototype glove group by in-service glove size

Best-fitting In-service Glove Size	No. of Subjects in Unlined Prototype Glove Acceptable Fit Group	No. of Subjects in Complete Sample	% of Subjects Who Met Acceptable Fit Criteria with Unlined Prototype Glove	
Males				
XS	11	31	(11/31)	35
S	33	74	(33/74)	45
M	86	140	(86/140)	61
L	56	80	(56/80)	70
XL	16	33	(16/33)	48
sample size	*(n=202)*	*(n=358)*		
Females				
XS	20	128	(20/128)	16
S	8	28	(8/28)	29
M	7	19	(7/19)	37
L	3	3	(3/3)	100
XL	-	-	-	
sample size	*(n=38)*	*(n=178)*		

3.3.3.1 Hand dimensions and glove fit

In order to investigate the role that specific hand dimensions played in glove size selection, summary statistics were generated for nine hand dimensions that are considered key glove sizing dimensions. These dimensions include: hand length, digit I length, digit II length, crotch I height, crotch III height (palm length), digit I interphalangeal (IP) girth, digit II proximal interphalangeal (PIP) girth, palm girth and hand volume. Summary statistics for these hand dimensions were generated for each in-service glove size, for the unlined prototype glove and for the lined prototype glove. Only the dimensions of those subjects whose responses met the acceptable fit criteria for the glove in question were considered. The male hand dimension summary statistics are presented in Table 3-8. The female hand dimension summary statistics are presented in Table 3-9.

Examination of these hand dimensions for the *male* subjects reveals that, *without exception*, the mean hand dimensions for the unlined prototype glove fell between the mean hand dimensions for the medium and large in-service glove sizes. These results support earlier observations that the prototype glove size best accommodated those subjects who had selected the medium (61%) and large (70%) in-service glove sizes (refer to Table 3-7).

The in-service glove sizes were too limited for the females, and the "long"/"loose" fit problems were of much greater frequency for the females with the prototype glove than the in-service glove. Therefore, a comparison of in-service gloves size to prototype glove size was not meaningful for the females.

The sections that follow address fitting aspects of the prototype CB protective glove when worn with a liner underlayer.

Table 3-8. Male hand dimension summary statistics by handwear condition

Hand	Best-fitting in-service CW Glove					Prototype Glove	
Dimension	XS	S	M	L	XL	Unlined	Lined
Hand Length (cm)							
Mean	18.24	18.39	18 94	19 33	20 09	19.04	18 96
SD	0 65	0.77	0 64	0 70	1 00	0.79	0 78
Range	2.30	3 50	3.25	4 10	4 40	4.65	5 00
Dgt I Length (cm)							
Mean	6 33	6 34	6.56	6.77	6 93	6 61	6 57
SD	0 29	0 33	0 36	0 37	0 46	0 40	0 38
Range	0 95	1 60	1 75	1 60	2 10	2 20	2 20
Dgt II Length (cm)							
Mean	7 03	7 04	7.24	7 49	7 78	7 32	7 28
SD	0 41	0 33	0.33	0 39	0.45	0 40	0 39
Range	1 80	1 90	1.80	1 60	1 80	2 35	2 35
Crotch I Height (cm)							
Mean	5 84	6 03	6.23	6.24	6 54	6 23	6.21
SD	0 55	0 53	0.60	0.54	0.64	0 56	0.58
Range	2 05	2 75	3 00	2.15	2 20	2 55	3 00
Palm Length (cm)							
Mean	10 47	10.62	10 87	11 02	11 58	10.92	10.88
SD	0 41	0 49	0.45	0.44	0 61	0.50	0 50
Range	1 60	2 40	2 30	2.05	2 25	2.80	2.90
Palm Breadth (cm)							
Mean	8 52	8 67	8 90	9 09	9 49	8 93	8 89
SD	0 29	0.29	0 33	0 29	0 36	0.38	0 37
Range	1 13	1.33	1 65	1 38	1.35	1.88	1 70
Dgt I IP Girth (cm)							
Mean	6 68	6 87	7.01	7 17	7 49	7 06	7.00
SD	0.23	0 29	0 30	0 27	0 23	0.33	0 34
Range	0.90	1 30	1 60	1.20	0 80	1.70	1 70
Dgt II PIP Girth (cm)							
Mean	6 45	6.56	6 74	6.92	7 22	6 79	6 75
SD	0.22	0 23	0.25	0 28	0 25	0 31	0 31
Range	0.75	1 15	1 15	1 10	0.90	1 55	1 60
Palm Girth (cm)							
Mean	20 19	20 72	21 25	21.72	22 62	21 31	21 21
SD	0 52	0.65	0 75	0 71	0.83	0 89	0.86
Range	1 85	2 45	3 90	3 95	3 30	4 50	4.50
Hand Volume (ml)							
Mean	361 8	382 4	410.3	434.7	503.8	415.9	409.0
SD	26.6	29 6	31.0	30 9	45 3	43.1	41.0
Range	113.0	130 0	159.0	128 0	163 0	258.0	217.0
Sample Size (n)	26	67	103	62	22	202	214

Table 3-9. Female hand dimension summary statistics by handwear condition

Hand	Best-fitting In-service CW Glove					Prototype Glove	
Dimension	XS	S	M	L	XL	Unlined	Lined
Hand Length (cm)							
Mean	17.20	17 76	18 25	19 80	-	17 75	17.53
SD	0 73	0 73	0 77	0 14	-	0.90	0 91
Range	3.55	3 35	2 90	0 20	-	3.65	3 65
Digit I Length (cm)							
Mean	6 00	6 15	6 37	6 70	-	6.14	6 08
SD	0 36	0 28	0.44	0 57	-	0.42	0 34
Range	1 70	1 45	1 50	0.80	-	1 90	1.40
Digit II Length (cm)							
Mean	6 66	6 89	7.10	7.85	-	6 92	6 79
SD	0.31	0.39	0 38	0.07	-	0.44	0 44
Range	1 35	1 50	1 65	0 10	-	1.95	1 90
Crotch I Height (cm)							
Mean	5 53	5 67	5 90	6 00	-	5 60	5 43
SD	0 55	0 51	0 60	0.57	-	0 48	0 50
Range	3 10	2 05	2 35	0 80	-	1.95	2 00
Palm Length (cm)							
Mean	9 84	10.09	10 45	11 08	-	10 12	10 06
SD	0 48	0 41	0.43	0.04	-	0 47	0 52
Range	2 25	2 10	1 50	0 05	-	1 95	2 05
Palm Breadth (cm)							
Mean	7 84	8.15	8 27	8 72	-	8 02	7 95
SD	0 34	0 33	0 40	0 21	-	0 44	0 44
Range	1 72	1 24	1 22	0.30	-	1.87	1 88
Digit I IP Girth (cm)							
Mean	6.07	6 20	6 40	6 55	-	6 17	6 15
SD	0 26	0.24	0 37	0.00	-	0 33	0 31
Range	1.30	0.90	1.15	0 00	-	1 20	1.55
Digit II PIP Girth (cm)							
Mean	5 89	6 10	6 14	6 38	-	6.00	5.94
SD	0 25	0 23	0 32	0 04	-	0 33	0.32
Range	1 10	0 80	1 00	0 05	-	1 15	1.20
Palm Girth (cm)							
Mean	18 44	19 15	19 48	20 15	-	18.88	18 70
SD	0 73	0 79	0 99	0.50	-	0 97	0 98
Range	3 85	3 05	3 10	0 70	-	4 65	4 40
Hand Volume (ml)							
Mean	281 0	308 6	331 4	368 5	-	299.3	292.6
SD	32 3	28 9	42.7	3 54	-	39.8	38.4
Range	136 0	104 0	154 0	5 0	-	155 0	148 0
Sample Size (n)	86	22	14	2	-	38	39

3.4 Evaluation of the lined prototype glove

As part of the *CF Glove Fit Study* a fit evaluation was also completed for the prototype CB protective glove when it was worn with a thin glove liner as an underlayer. The fit of this glove and liner combination -- lined prototype glove -- was evaluated in order to determine what affect the liner had on the fit of the prototype glove.

The questionnaire used to evaluate the fit of the lined prototype glove was identical to that used for the unlined prototype glove, except that it included a short section that addressed only the fit of the liner. The results of the liner fit evaluation are presented in the following section.

3.4.1 Glove liner fit

Before the fit of the lined prototype glove was evaluated, the fit of the liner alone was evaluated. Subjects were required to select the liner size that fit them best from the four available sizes (small, medium, large and extra-large). Before selecting the best fitting liner size, subjects were instructed that the liner was designed to fit snugly on their hands. They were also told that the liner should fit well into the finger crotches and should be smooth at the fingertips.

Size distributions for the glove liner are presented in Figure 3-12 for the males and Figure 3-13 for the females. The medium and large liner sizes were the most popular for males, while the small and medium sizes were the most popular for females. The lighter bars of Figure 3-12 and Figure 3-13 present the size distributions for the complete samples. The darker bars present the size distributions for the acceptable fit groups. Liner fit was considered acceptable if the overall fit rating for the liner was less than or equal to "3", "somewhat good".

Acceptable liner fit was achieved by 95% of the male subjects and 95% of the female subjects. The size-specific acceptability ratios for the liner were generally quite high. However, 20% of male subjects who chose the extra-large liner size as best fitting did not meet the acceptable fit criteria for the liner. The male acceptability ratios for the other sizes were very high: 94% for the small size, 98% for the medium size and 98% for the large size Acceptability ratios for the liner sizes were also high for the females: 91% for the small size, 96% for the medium size, 100% for the large size and 83% for the extra-large size. It should be noted that only six females chose the extra-large liner size; therefore the acceptability ratio may be misleading for the females at this size.

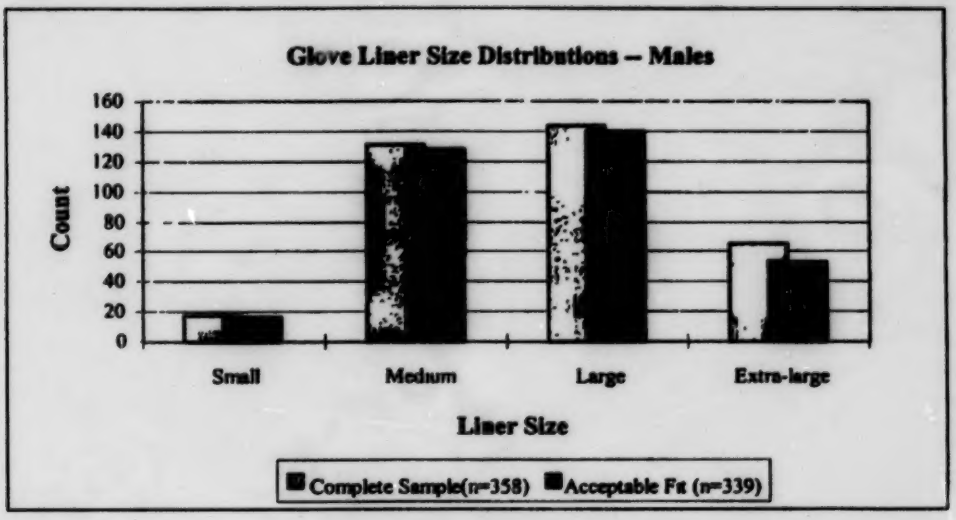


Figure 3-12. Male size distributions for glove liner

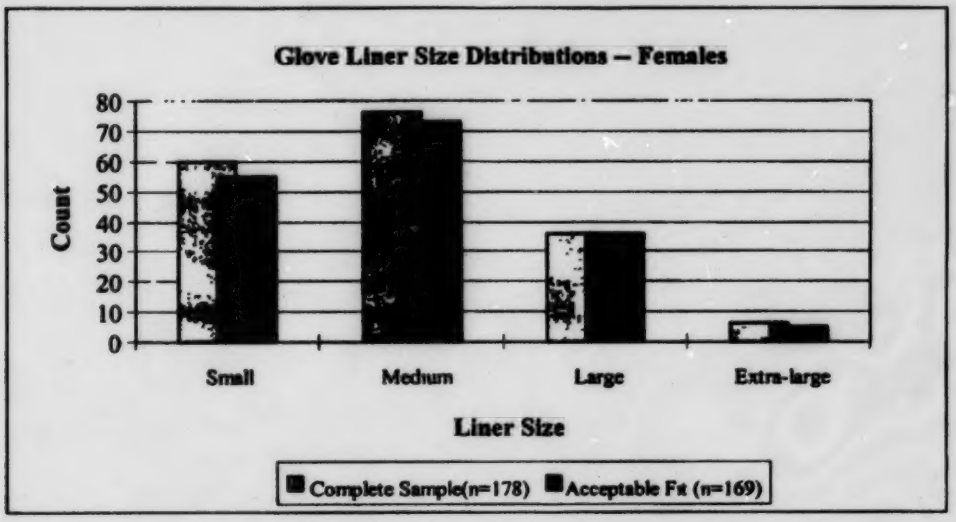


Figure 3-13. Female size distributions for glove liner

Besides the high fit acceptability ratios for the glove liner, the liner also received very favourable overall fit ratings. Mean ratings for the overall fit of the glove liner were 1.91 for the complete male sample and 1.73 for the male acceptable fit group. In terms of the females, the mean overall fit ratings for the glove liner were 1.88 for the complete sample and 1.78 for the acceptable fit group. Thus, the mean overall fit ratings for both genders were always between the "very good" and "good" fit qualifiers.

In summary, the liner sizing system resulted in acceptable liner fit for approximately 95% of the CF personnel who participated in the study. Liner fit acceptability was relatively lower at the extreme sizes (i.e., small and extra-large liner sizes).

3.4.2 Range of lined prototype glove fit

In order to establish the percentages of male and female subjects that were accommodated by the prototype glove when the liner was worn, the acceptable fit criteria were employed (refer to Section 3.1, "Criteria for Acceptable Glove Fit"). The criteria were expanded to include consideration for the fit of the glove liner. Therefore, acceptability criteria were met for the lined prototype glove if the subject answered:

- "yes" to the question relating to successful task performance, **and**
- less than or equal to "3", "somewhat good", for the overall glove fit rating, **and**
- less than or equal to "3", "somewhat good", for the overall liner fit rating.

Adding consideration for the liner overall fit rating had very little effect on the sizes of the acceptable and unacceptable fit groups. The expanded criteria only resulted in the additional exclusion of one male and one female from the respective acceptable fit groups for the lined prototype glove.

The questionnaire responses revealed that 59.8% of male subjects met the criteria for acceptable glove fit and 21.9% of female subjects did. The male percentage was slightly higher for the lined prototype than it had been for the unlined prototype (59.8% versus 56.4%, respectively); while the female percentages were almost identical (21.9% for the lined prototype and 21.3% for the unlined).

Even though the numbers of subjects within the acceptable fit groups for the lined prototype glove were very similar to those for the unlined prototype glove, there were differences in the composition of these groups. The differences between these groups are relevant in that they provide some information on the effect of the liner on the fit of the prototype glove. One way to examine the differences is to compare the in-service CW lightweight glove size distributions for the unlined and lined prototype glove acceptable fit groups. These distributions are presented in Table 3-10.

Table 3-10. Distributions for lined and unlined prototype glove acceptable fit groups by in-service glove size

Best-fitting In-service Glove Size	Subjects Who Met Acceptable Fit Criteria for the Prototype Glove			
	Lined		Unlined	
	Ratio	Percent	Ratio	Percent
Males				
XS	(15/31)	48	(11/31)	35
S	(48/74)	65	(33/74)	45
M	(91/140)	65	(86/140)	61
L	(49/80)	61	(56/80)	70
XL	(11/33)	33	(16/33)	48
Females				
XS	(24/128)	19	(20/128)	16
S	(8/28)	29	(8/28)	29
M	(5/19)	26	(7/19)	37
L	(2/3)	67	(3/3)	100
XL		-		-

The in-service glove size distribution for the lined prototype male acceptable fit group was clearly different than that for the unlined prototype glove. The most common in-service glove sizes for males with the *lined* prototype glove were the small, medium and large sizes -- that is, 65%, 65% and 61%, respectively, of males at these in-service glove sizes met the criteria for acceptable fit with the lined prototype glove. In contrast, the most common in-service glove sizes for the *unlined* prototype glove were the medium and large sizes -- that is, 61% and 70%, respectively, of males at these in-service glove sizes met the criteria for acceptable glove fit with the unlined prototype. Therefore, wearing the liner underlayer with the prototype glove resulted in more subjects from the smaller sizes of the in-service glove achieving acceptable fit, and fewer subjects from the larger sizes of the in-service glove achieving acceptable fit. A similar shift in the lined and unlined prototype size distributions was apparent for the female acceptable fit groups (bottom half of Table 3-10).

In order to investigate this shift of subjects between the groups, the characteristics of four partitions of subjects were examined. These partitions are described below.

1. Partition I -- unlined prototype glove fit acceptable but lined prototype glove fit unacceptable -- 32 of the 202 men (15.8%) who met the acceptable fit criteria for the unlined prototype glove did not meet the criteria with the lined glove. This partition consists of 8.9% of the complete male sample (i.e., $^{32}/_{358}$).

2. Partition II -- unlined prototype glove fit acceptable and lined prototype glove fit acceptable -- 170 men met the acceptable fit criteria for both the lined and the unlined prototype glove conditions. This partition consists of 47.5% of the complete male sample (i.e., $^{170}/_{358}$).

3. Partition III -- lined prototype glove fit acceptable but unlined prototype glove fit unacceptable -- 44 of the 214 men (20.6%) who met the acceptable fit criteria for the lined prototype glove did not meet the criteria with the unlined glove. This partition consists of 12.3% of the complete male sample (i.e., $^{44}/_{358}$).

4. Partition IV -- unlined prototype glove fit unacceptable and lined prototype glove fit unacceptable -- 112 men did not meet acceptable fit criteria for the lined prototype glove and the unlined glove. This partition consists of 31.3% of the complete male sample (i.e., $^{112}/_{358}$).

Figure 3-14 demonstrates this partitioning of male subjects for the lined and unlined prototype gloves. These partitions demonstrate that, relative to the complete male sample, there was an *average* shift of approximately 11% of men into and out of the lined prototype acceptable fit group as a result of wearing the liner underlayer.

In order to further examine the effect of the glove liner on the fit of the prototype gloves, mean values for a selection of hand dimensions for the first three of these partitions were generated. These means are presented in Table 3-11. Slightly smaller mean girths were apparent for the subjects who achieved acceptable fit with the lined but not the unlined prototype glove. Conversely, slightly larger mean girths were apparent for the subjects who achieved acceptable fit with the unlined but not the lined prototype glove. When acceptable fit criteria were met for both the lined and unlined gloves the mean hand dimensions were located mid-way between the other two groups.

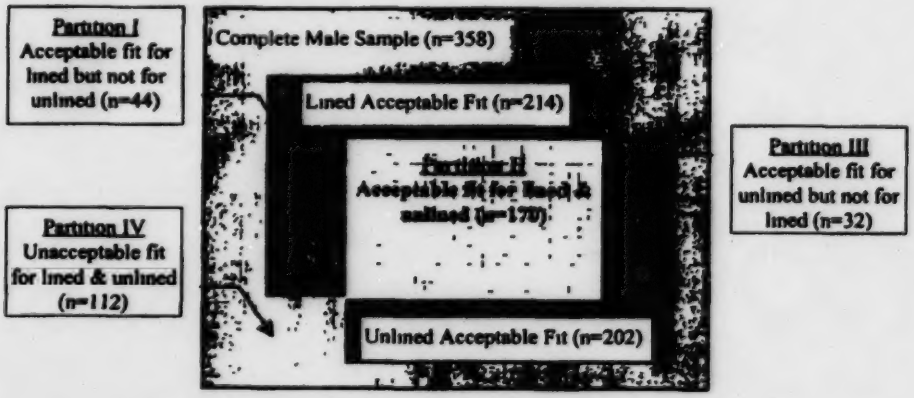

Partition I
Acceptable fit for lined but not for unlined (n=44)
Partition IV
Unacceptable fit for lined & unlined (n=112)
Complete Male Sample (n=358)
Lined Acceptable Fit (n=214)
Partition II
Acceptable fit for lined & unlined (n=170)
Unlined Acceptable Fit (n=202)
Partition III
Acceptable fit for unlined but not for lined (n=32)

***Figure 3-14.** Partitioning of male subjects for lined and unlined prototype gloves between acceptable and unacceptable fit groups*

Table 3-11. Mean hand dimensions for partitions of male lined and unlined prototype glove groups

Hand Dimension	Partition I Lined Prototype Fit Acceptable, Unlined Fit Not Acceptable	Partition II Both Lined and Unlined Prototype Fit Acceptable	Partition III Unlined Prototype Fit Acceptable, Lined Fit Not Acceptable
Sample Size (n)	44	170	32
Hand Length (cm)	18 69	19.03	19.14
Digit I Length (cm)[1]	6.51$_a$	6.59$_a$	6.77$_b$
Digit II Length (cm)	7 20	7 30	7 42
Digit III Length (cm)	7.92	8.07	8 18
Digit IV Length (cm)	7 39	7 51	7 68
Digit V Length (cm)	6 01	6.03	6 23
Crotch I Height (cm)	6.08	6.25	6.17
Palm Length (cm)	10.76	10.91	10.94
Palm Breadth (cm)	8 80	8 91	9 04
Digit I IP Girth (cm)[1]	6.88$_a$	7 04$_b$	7.16$_b$
Digit II PIP Girth (cm)[1]	6 64$_a$	6 77$_{a,b}$	6 88$_b$
Digit II DIP Girth (cm)[1]	5 59$_a$	5 71$_a$	5.79$_b$
Digit III PIP Girth (cm)[1]	6 71$_a$	6 86$_b$	6.92$_b$
Digit III DIP Girth (cm)[1]	5 61$_a$	5.76$_b$	5.84$_b$
Digit IV PIP Girth (cm)[1]	6 29$_a$	6.44$_b$	6 53$_b$
Digit V PIP Girth (cm)[1]	5.64$_a$	5.77$_a$	5 91$_b$
Wrist Girth (cm)[1]	17 16$_a$	17 45$_{a,b}$	17.73$_b$
Palm Girth (cm)	20.99	21.27	21.58
Flexed Forearm Girth (cm)[1]	28 73$_a$	29 09$_a$	30.01$_b$
Hand Volume (ml)[1]	395 6$_a$	412 5$_a$	434.1$_b$

Note: Means with the same subscript letter are not significantly different (α= 05)

[1] Significant effect of group partition on hand dimension (α= 05)

One-factor GLM ANOVAs were performed for the dimensions listed in Table 3-11 with partition as the independent variable. The results of these analyses are summarized in Table 3-11 Hand dimensions significantly influenced by the partitions are identified by the cross symbol (†). Significantly different partition means are identified using letter subscripts, where means with the same subscript letter are not significantly different. The main observations regarding these analyses are summarized below

- Mean length dimensions were generally not significantly different between the partitions.
- Mean digit girths were significantly smaller for the lined acceptable and unlined unacceptable partition (partition I) than the unlined acceptable and lined unacceptable partition (partition III). The average difference between these means was 0.24 cm.
- Mean wrist girth was smaller for partition I than partition III. The average difference between these means was 0.57 cm.
- Mean palm girth was not significantly different between the partitions.
- Mean flexed forearm girth was smaller for partition I than for partition III. The average difference between these means was 1.28 cm.
- Mean hand volume was smaller for partition I than for partition III. The average difference between these means was 38.5 ml.

The differences in hand dimensions between the partitions of subjects demonstrate the general effect of the liner underlayer on the fit of the prototype glove. The liner consumes a degree of the ease available within the prototype glove. This change in ease appears to have a significant effect on the hand sizes that are accommodated by the lined prototype glove. The hand dimensions that are significantly affected include many of the girth dimensions; namely, digit girth, wrist girth and forearm girth; as well as digit I length. The change in ease resulting from the addition of the liner enabled some male subjects (12.3% of total), those with relatively smaller hands (especially in girth dimensions), to achieve acceptable fit with the prototype glove and liner combination, when they had not been able to achieve acceptable fit without the liner. Conversely, this consumption of ease resulted in some male subjects (8.9% of total), those with relatively larger hands (especially in girth dimensions), to be unable to meet acceptable fit criteria with the liner and glove combination, when they had achieved acceptable fit with the unlined prototype. However, the 47.5% of the complete male sample met acceptable fit criteria for both the lined and unlined prototype glove.

Note that the female data was not examined using similar partitions because of the small sample sizes comprising the acceptable fit groups for the prototype glove conditions.

3.4.3 Nature of fit for the lined prototype glove

The nature of fit for the lined prototype glove was assessed by examining the overall fit rating responses as well as fit problems specific to certain areas of the glove.

3.4.3.1 Overall fit ratings for the lined prototype glove

Table 3-12 presents mean overall fit ratings for the lined prototype glove. Mean ratings are presented for both genders for the acceptable fit and unacceptable fit groups. Mean ratings for the unlined prototype glove and in-service glove are included for comparison purposes.

Table 3-12. Mean overall fit ratings for lined prototype, unlined prototype and in-service gloves

	Lined Prototype Glove		Unlined Prototype Glove		In-service Glove	
	Acceptable Fit Group	Unacceptable Fit Group	Acceptable Fit Group	Unacceptable Fit Group	Acceptable Fit Group	Unacceptable Fit Group
Males						
Mean	2.40	4 66	2 45	4 63	2.27	4 26
SD	0 58	1.21	0 61	1.10	0.63	1.04
η	214	144	202	156	280	78
Females						
Mean	2.49	5 49	2 61	5 81	2 29	4 61
SD	0 64	1 18	0 55	1.07	0 68	1 05
η	39	139	38	140	124	54

Note. Overall glove fit was based on a seven-point scale where "very good" overall fit was equated to "1" and "very poor" fit was equated to "7"

In terms of the lined prototype glove, the mean overall fit ratings, for both the male and female *acceptable* fit groups are approximately mid-way between the "good" ("2") and "somewhat good" ("3") fit qualifiers (mean ratings of 2.40 and 2.49, respectively). Considering only the male *acceptable* fit groups, the mean overall fit rating for the lined prototype glove (2.40) was very similar to that of the unlined prototype glove (2.45) as well as that of the in-service glove (2.27). Considering only the female *acceptable* fit groups, the mean overall fit rating for the lined prototype glove (2.49) was somewhat closer to that of the in-service glove (2.29), than the rating for the unlined prototype glove had been (2 61). Therefore, when acceptable fit criteria were met, it appears that the glove liner slightly improved the overall fit ratings for the prototype glove, especially for the females.

When only the *unacceptable* fit groups are considered, the mean male overall fit rating for the lined prototype glove was almost identical to that received for the unlined prototype glove (4.66 versus 4.63, respectively). The mean female unacceptable fit group overall fit rating for the lined glove was somewhat better than that received for the unlined glove (5 49 versus 5.81, respectively).

3.4.3.2 Fit problem areas for the lined prototype glove

Subjects were asked to identify fit problem areas on the lined prototype glove, as they had been asked to do for the unlined prototype and in-service gloves. The fit problem area responses for the lined prototype glove are described in the following sections.

3.4.3.2.1. Fit problems for male subjects

Figure 3-15 presents the frequencies of fit problem area responses for the male *acceptable* fit group. The fit problem frequency chart for the lined prototype glove is essentially identical to that of the unlined prototype glove (see

Figure 3-8). There is only one obvious difference between the two charts, and that is related to the finger girth fit problems. For the unlined prototype, fit problems in finger girth were reported by approximately 30% of the group, but a clear majority of responses were reported on the "loose" extreme. For the lined prototype, however, a similar frequency of finger girth problems were reported (i.e., approximately 30%), yet these were evenly split between the "too tight" and "too loose" extremes.

Figure 3-16 presents the frequencies of fit problem area responses for the male *unacceptable* fit group. This chart clearly demonstrates a sharing of "too small" and "too large" responses for all areas of the glove, except cuff girth where the "too loose" responses prevail It appears that for the male subjects, the addition of the glove liner placed the prototype glove size in a very central location.

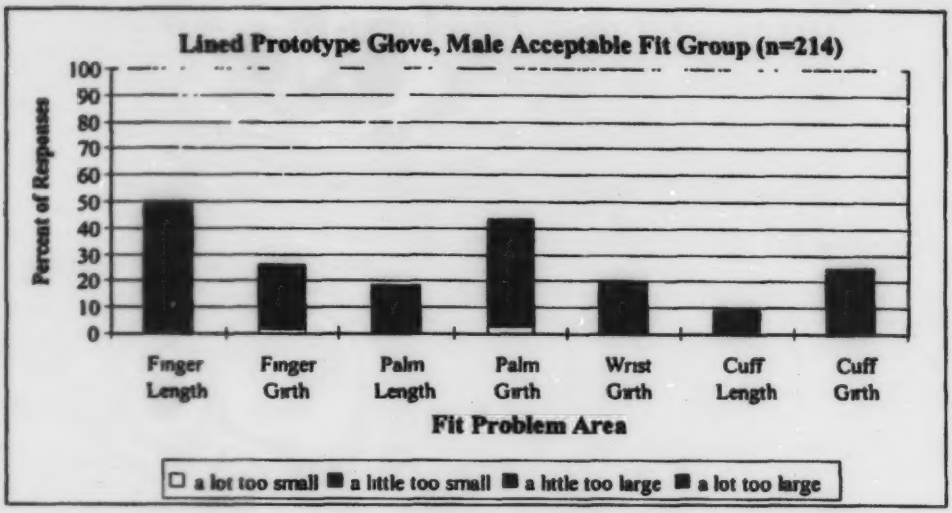


Figure 3-15. Frequency of area specific fit problems for male subjects within the lined prototype glove acceptable fit group.

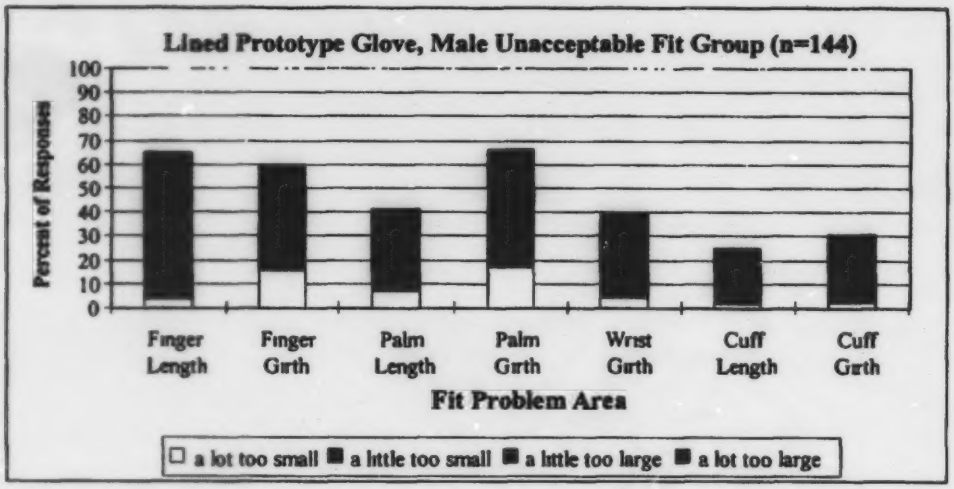


Figure 3-16. Frequency of area specific fit problems for male subjects within the lined prototype glove unacceptable fit group.

Mean fit problem ratings for the lined and unlined prototype gloves male acceptable and unacceptable fit groups are presented in the top-half of Table 3-13 The mean male fit problem area ratings for the lined prototype glove acceptable fit group were very similar to those of the unlined prototype glove. Finger length, cuff length, and cuff girth mean fit problem ratings were very similar for the lined and unlined prototype male acceptable fit groups. There were some small differences between the handwear conditions These differences are summarized below.

- Finger girth mean rating was at the optimal level for the lined prototype while it was slightly loose for the unlined prototype.
- Palm length was somewhat longer for the lined prototype compared to the unlined prototype.
- Palm girth and wrist girth mean fit problem ratings were closer to the optimal level for the lined prototype compared to the unlined prototype.

Considering the male unacceptable fit groups it was clear that the liner resulted in a smaller fitting prototype glove. This effect was apparent in finger girth, palm length, palm girth and wrist girth.

3.4.3.2.2. Fit problems for female subjects

Figure 3-17 presents the frequencies of fit problem area responses for the female *acceptable* fit group. Figure 3-18 presents the frequencies of fit problem area responses for the female *unacceptable* fit group. The response frequencies for the lined and unlined prototypes (see Figure 3-10 and Figure 3-11 for unlined prototype charts) are reasonably similar, except for the following two observations.

- In general, the lined prototype *acceptable* fit group received a lower ratio of "a lot too large" : "a little too large" responses, relative to the ratio for the unlined prototype glove acceptable fit group.
- In general, the lined prototype *unacceptable* fit group received approximately 10% fewer "too loose" finger girth fit problems compared to the unlined prototype glove.

Table 3-13. Mean fit problem area ratings for lined prototype and unlined prototype gloves

Fit Problem Area	Lined Prototype Glove		Unlined Prototype Glove	
	Acceptable Fit Group	Unacceptable Fit Group	Acceptable Fit Group	Unacceptable Fit Group
Males				
Finger Length	3.25	3.34	3.28	3.62
Finger Girth	2.99	2.72	3.18	3.47
Palm Length	3.07	2.93	3.01	3.12
Palm Girth	3.13	2.85	3.20	3.28
Wrist Girth	3.10	2.92	3.20	3.20
Cuff Length	3.05	3.03	3.07	3.10
Cuff Girth	3.26	3.22	3.27	3.37
η	214	144	202	156
Females				
Finger Length	4.22	4.55	3.97	4.68
Finger Girth	4.03	4.34	4.16	4.56
Palm Length	3.67	3.96	3.45	4.11
Palm Girth	4.08	4.42	4.03	4.60
Wrist Girth	4.08	4.15	3.87	4.50
Cuff Length	3.56	3.65	3.34	3.77
Cuff Girth	3.95	4.04	3.76	4.29
η	39	139	38	140

Note. Fit problem area responses coded as: "a lot too short/tight" = "1", "a little too short/tight" = "2", no reported fit problem = "3", "a little too long/loose" = "4", and "a lot too long/loose" = "5"

Mean fit problem area ratings for the lined and unlined prototype gloves for the female acceptable and unacceptable fit groups are presented in the bottom-half of Table 3-13. Some differences were evident for the female acceptable fit groups between the lined and unlined mean fit problem ratings. The largest differences between these two groups were in finger length, palm length, wrist girth and cuff length. These results are difficult to interpret as it was expected that the glove liner would affect girth fit more than length fit. It was also expected that the liner would result in a smaller fit, where the numbers generally indicate a slightly larger fit. All in all, considering both the acceptable and unacceptable fit groups for the lined prototype glove, the female fit problem area responses indicated a poor fit.

3.4.3.3 Nature of lined prototype glove fit – Conclusions

The lined prototype glove provided a reasonably good fit for those men whose questionnaire responses met the criteria for acceptable glove fit. However, the men in this group did experience some fit problems with the glove. Glove finger length was frequently rated as "a little long"; glove palm girth and wrist girth were frequently rated as "a little too loose"; and glove cuff girth was often considered " a lot too loose".

The lined prototype glove provided a poor fit for women, just as the unlined prototype glove had. This poor fit was evident in the small number of women whose responses met the criteria for acceptable glove fit (21.9%); it was evident in the relatively high mean overall fit ratings for the lined prototype glove (i.e., closer to the "very poor" fit qualifier); and it was evident in the high frequency of fit problem areas reported for the glove. Similar to the results for the unlined prototype glove, the lined prototype glove was too large for almost all female participants across a wide range of glove dimensions.

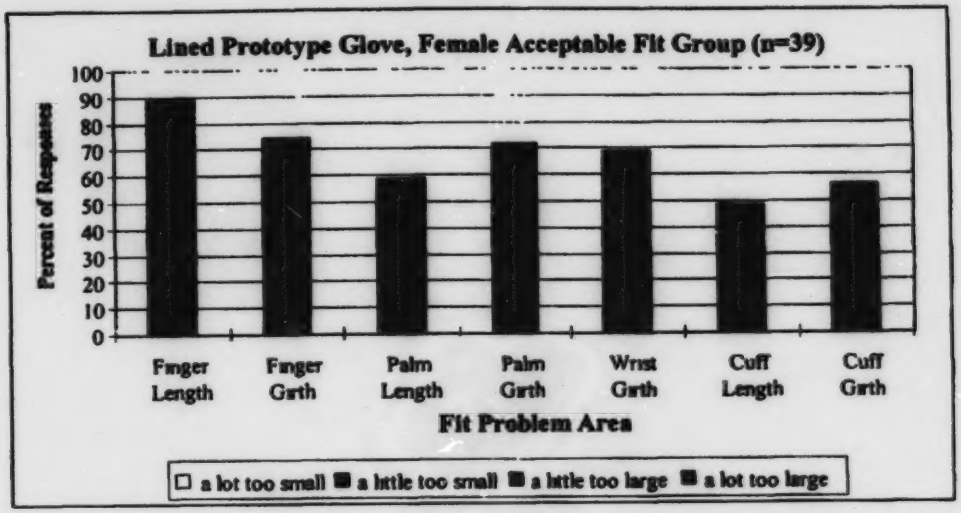


Figure 3-17. Frequency of area specific fit problems for female subjects within the lined prototype glove acceptable fit group

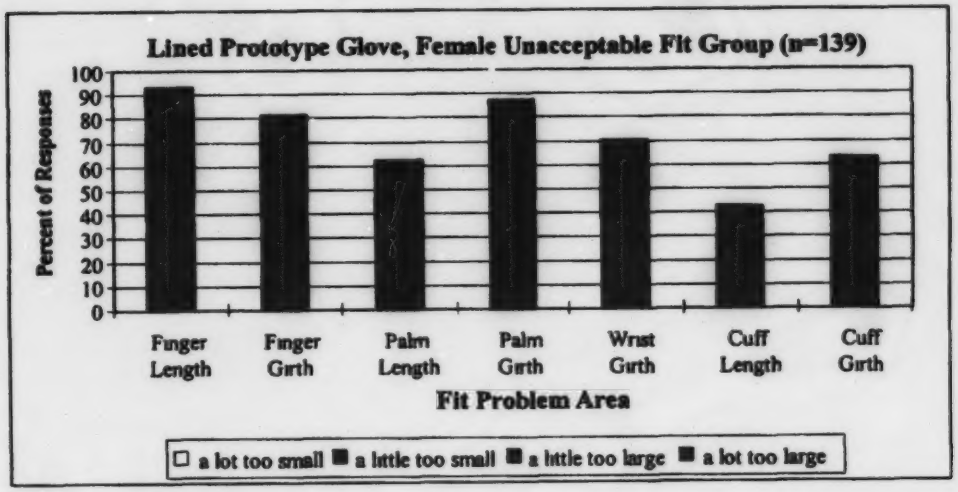


Figure 3-18. Frequency of area specific fit problems for female subjects within the lined prototype glove unacceptable fit group.

4. Summary & conclusions

This chapter presents a summary of the main results from the glove fit assessment. It also presents the conclusions that can be drawn from these results. The summary is presented according to the six main questions related to glove fit that the study sought to solve.

4.1 Question 1 – Range of in-service CW lightweight glove fit

One question that the *CF Glove Fit Study* sought to answer was: what percentage of the CF population is accommodated by the five-size system of the in-service CW lightweight glove?

4.1.1 Range of in-service glove fit for males

- 78.2% of male participants (280 out of 358) met acceptable fit criteria with the in-service CW lightweight glove.
    - The male participants most frequently chose the medium size glove as the best fitting size.
        - 39.1% of the complete male sample selected the medium size as the best fitting size (i.e., $^{140}/_{358}$).
        - Relative to the complete male sample, 28.8% of men met acceptable fit criteria for the medium size in-service glove (i.e., $^{103}/_{358}$).
    - The male subjects were normally distributed among the five in-service glove sizes. *Considering only those men whose met acceptable fit criteria*: 9.3% chose the extra-small size as the best fitting size, 23.9% chose the small, 36.8% chose the medium, 22.1% chose the large and 7.9% chose the extra-large.
    - The medium, large and extra-large sizes were less successful in providing acceptable fit than the extra-small and small sizes were. That is, the acceptable fit to unacceptable fit ratio was higher for the smaller in-service CW glove sizes than the larger sizes.

4.1.2 Range of in-service glove fit for females

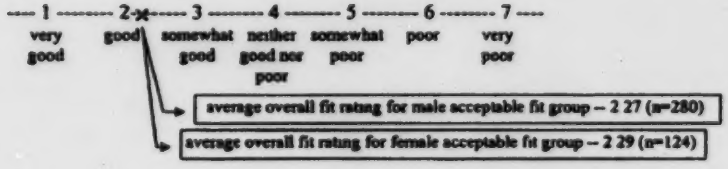
- 69.7% of female participants (124 out of 178) met acceptable fit criteria with the CW lightweight glove
    - More than two-thirds of the female participants, 71.9% selected the extra-small size as best fitting (i.e., $^{128}/_{178}$). The extra-small size was the smallest size available.
    - The female participants were clearly *not* normally distributed among the five in-service glove sizes. *Considering only those women who met acceptable fit criteria*: 69.4% chose the extra-small size, 17.7% chose the small size, 11.3% chose the medium size and 1.6% chose the large size as best fitting. None of the female participants chose the extra-large in-service glove size as best fitting.

4.2 Question 2 – Nature of fit provided by in-service CW lightweight glove

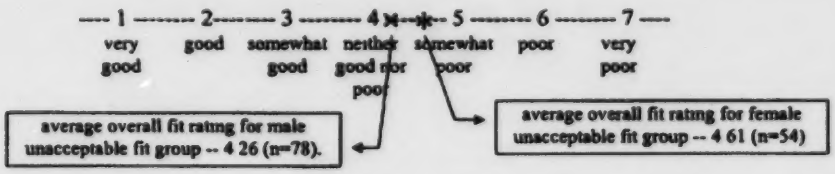
The *CF Glove Fit Study* also sought to gather information on the fit characteristics of the in-service CW lightweight glove.

4.2.1 Overall fit ratings for in-service glove

- When acceptable fit criteria were met, the overall fit of the in-service glove was rated quite favourably. The average rating was very close to the "good" fit qualifier for both genders.



- When acceptable fit criteria were not met, the mean in-service glove overall fit ratings were between the "neither good nor poor" and "somewhat poor" qualifiers. The mean ratings were slightly worse for the females than for the males.



4.2.2 Area specific fit problems for in-service glove

4.2.2.1 Males

- Area specific fit problems were apparent for men with the in-service glove *even when the criteria for acceptable fit were met*. The most frequent fit problems for this group were: finger length fit: "a little too long", and palm girth fit: "a little too loose".
    - The "long" fit in finger length was only evident with the medium, large and extra-large in-service CW glove sizes. Finger length fit for the small and extra-small sizes was not problematic.
    - The "loose" fit in palm girth was common to **all** of the in-service glove sizes.
- Relatively high frequencies of area specific "a little too long"/"a little too loose" fit problems were apparent for men in the *unacceptable fit group* for all glove areas except cuff girth. These results reveal that when none of the in-service glove sizes provided acceptable fit, the male participants tended to select a larger fitting glove size rather than a smaller fitting size as best fitting.
    - The "long"/"loose" fit problems were especially apparent in finger length fit and palm girth fit for the male *unacceptable fit group*. Therefore, the problems noted by men in the unacceptable fit group were similar to, but more pronounced than, those noted by men in the acceptable fit group.
- The extra-small and small in-service glove sizes provided better overall fit for the male participants than the medium, large and extra-large sizes had.
    - The extra-small and small sizes demonstrated overall fit ratings that were closer to the "very good" extreme than the medium, large and extra-large sizes had.
    - The extra-small and small sizes demonstrated higher acceptable fit ratios than the medium, large and extra-large sizes had.
    - Excessive finger length fit problems were infrequently reported for the extra-small and small glove sizes, but they were commonly reported for the larger sizes -- medium, large and extra-large.

4.2.2.2 Females

- The small size in-service glove provided a relatively good fit for women in the *acceptable fit group*, except in palm girth and wrist girth, which were both frequently, rated as "a little too loose".

- On the whole, however, the female participants reported higher frequencies of fit problems and more severe fit problems with the in-service glove than the male participants had reported, even when only the acceptable fit group was considered These results reflect the fact that glove size choices were very limited for the females. That is, 69.4% of females in the acceptable fit group chose the extra-small glove size as best fitting, and this was the smallest size available

    - Women in the *acceptable fit group* reported higher frequencies and a higher severity of area specific fit problems, relative to the male *acceptable fit group* -- "a little too long"/"a little too loose" fit problems were frequently reported in finger length, finger girth, palm girth, wrist girth and cuff girth.

    - Over 70% of women in the *unacceptable fit group* reported "long"/"loose" fit problems in finger length, finger girth, palm girth and wrist girth. These results clearly demonstrate the need for smaller fitting gloves for female CF personnel.

4.3 Question 3 – Range of fit provided by the unlined prototype CB glove

The *CF Glove Fit Study* sought to gather information on the range of fit provided by the CB protective prototype glove size.

- A high percentage of men and a low percentage of women met the criteria for acceptable glove fit with the unlined prototype glove.

    - 56.4% of male participants (202 out of 358) met acceptable fit criteria with the unlined prototype glove size.

    - 21.3% of female participants (38 out of 178) met acceptable fit criteria with the unlined prototype glove size.

- The prototype glove size accommodated a large number of males. This high acceptability ratio for the males may be related to a number of aspects of the prototype glove design and/or the glove's design dimensions.

    - The corrugations applied to the digits, the thumb crotch and the palm of the prototype glove likely increased the range of length fit in these areas.

    - The prototype glove finger girths are considerably larger than those of comparable sizes of the in-service glove. Thus, the enhanced range of length fit resulting from the corrugations was not compromised by a lack of girth ease for larger hands.

- A number of key design dimensions for the prototype glove were based on dimensions from a nine-size chemical protective glove system developed by Robinette and Annis [8] -- i.e., some of the dimensions specified for the regular-large size of this nine-size system, the size with the highest tariff, were used Therefore, the prototype glove was designed as a size that would accommodate the largest proportion of the male population.

- It is possible that the acceptable fit criteria employed in the study were not stringent enough and thus the fit of the prototype glove was considered acceptable when it may not have been. However, if this was the case, since the same criteria were employed for the in-service CW glove the range of fit provided by the in-service glove would also have been lower than presented, and it was already quite low.

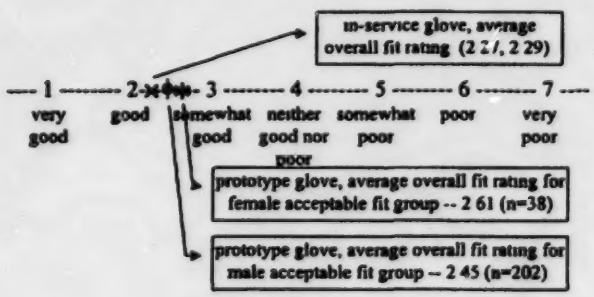
- Another aspect of the evaluation that must not be overlooked is that the fit assessment was completely subjective. The assessment was based on the subject's impressions of the glove fit after a short-term wear period, where no work related duties were performed. Therefore, how well these results will translate to the effectiveness of glove fit during the performance of realistic manipulative tasks is not known. However, this is true for the in-service glove as well as the prototype glove.

4.4 Question 4 – Nature of fit provided by the unlined prototype CB glove

The *CF Glove Fit Study* also sought to gather information on the fit characteristics of the unlined prototype glove.

4.4.1 Overall fit ratings for unlined prototype glove

- When acceptable fit criteria were met, the prototype glove received quite favourable overall fit ratings -- the average overall fit ratings were mid-way between the "good" and "somewhat good" fit qualifiers. The ratings for the prototype glove were slightly poorer than the ratings for the in-service glove.



4.4.2 Area specific fit problems for the unlined prototype glove

4.4.2.1 Males

- Area specific fit problems were apparent for men with the unlined prototype glove *even when the criteria for acceptable fit were met* Approximately 50% of men in the acceptable fit group found the fit of the glove in finger length and in palm girth problematic. Approximately two-thirds of these fit problems were on the "long"/"loose" extreme, while the other third were on the "short"/"tight" extreme.

- For the male *unacceptable fit group*, area specific fit problems were especially evident in finger length, finger girth, palm girth, wrist girth and cuff girth. In general, two-thirds of the problematic responses were on the "long"/"loose" extreme, while the other third was on the "short"/"tight" extreme. Two exceptions to this response pattern were noted: palm length and cuff length fit problem responses were split between the "too long" and "too short" extremes.

- In comparison to the in-service glove acceptable fit group responses, the unlined prototype glove was notably looser fitting in finger girth and cuff girth. Loose palm girth complaints were slightly less evident with the prototype glove than they had been with the in-service glove.

4.4.2.2 Females

- Even though 21.3% of female participants met the criteria for acceptable fit with the unlined prototype glove, this group reported very high frequencies of "long" and "loose" fit problem areas especially in finger length, finger girth, palm girth, wrist girth, cuff length and cuff girth.

    - The unlined prototype glove was too large for almost all female participants across almost all glove dimensions investigated.

4.5 Question 5 – Location of unlined prototype CB protective glove within in-service glove sizing system

The *CF Glove Fit Study* also sought to determine where the unlined prototype glove size was situated within the five-sizes of the in-service glove.

- For the *male* participants, the unlined prototype glove appears to have size characteristics similar to the medium and large in-service CW lightweight glove sizes. Mean male hand dimensions for the unlined prototype glove were always between the mean male hand dimensions for those men who had selected the medium size and those who had selected the large size of in-service glove as best

fitting. In-service glove size distributions for the prototype glove acceptable fit groups also supported these results.

- For the *female* participants, the in-service glove sizes were too limited to allow meaningful comparison of female hand dimensions across the sizes to those of the prototype glove size.

4.6 Question 6 – Effect of glove liner on fit of CB protective prototype glove

The *CF Glove Fit Study* also sought to determine what affect the glove liner had on the fit of the prototype glove.

4.6.1 Range of liner fit

- The liner itself met acceptable fit criteria for 95% of male participants and 95% of female participants The overall liner fit was rated between "very good" and "good" for both genders. The fit of the liner at the extreme sizes (i.e , small and extra-large) was relatively poorer than the fit of the mid-range sizes (i.e., medium and large).

4.6.2 Range of lined prototype glove fit

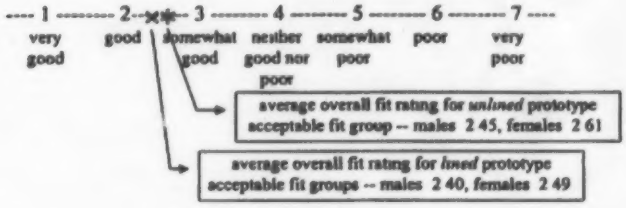
- The range of fit provided by the lined prototype glove was quite high for the males: 59.8% of male participants met the acceptable fit criteria with the lined prototype glove.

- The range of fit provided by the lined prototype glove was poor for the females: only 21.9% of female participants met the acceptable fit criteria with the lined prototype glove.

- Relative to the complete male sample (i.e., n=358) there was an average shift of approximately 11% of males into and out of the lined prototype acceptable fit group as a result of wearing the liner underlayer. That is, approximately 11% of men who did not meet acceptable fit criteria with the unlined prototype glove did meet the criteria when they wore the glove liner with the prototype. Similarly, approximately 11% of men who had met acceptable fit criteria with the unlined prototype glove, no longer did when they wore the liner underlayer.

4.6.3 Overall fit ratings for lined prototype glove

- The overall fit of the lined prototype glove was rated mid-way between the "good" and "somewhat good" fit qualifiers, by both males and females in their respective acceptable fit groups. The overall fit ratings were slightly better for the lined versus the unlined prototype handwear condition.



4.6.4 Fit problem areas for lined prototype glove

4.6.4.1 Males

- The lined prototype glove provided reasonably good fit for men who met the acceptable fit criteria. Some fit problems, however, were evident for this group: slightly long glove fingers, slightly loose glove palm and wrist, and very loose glove cuff. Similar frequencies of these fit problems were reported for the prototype glove worn without the liner underlayer.

- The only noticeable difference in fit problem areas between the unlined and lined prototype gloves for the male *acceptable fit groups* was in finger girth. The liner improved the fit of the prototype glove in finger girth. Fit problems were evenly spread between the "too loose" and the "too tight" extremes with the liner; whereas, without the liner fit problems on the "too loose" extreme had prevailed.

4.6.4.2 Females

- The lined prototype glove provided a very poor fit for women, *even those who met the acceptable fit criteria*, just as the unlined prototype glove had The glove was too large for almost all female participants across almost all dimensions.

4.7 Conclusions

The *CF Glove Fit Study* results demonstrated that the in-service lightweight protective glove sizing system did not provide very effective coverage of the sample of CF personnel involved in the study. Considerable effort was expended in order that the study sample would be representative of the CF population. As described in the first report on the study, personnel were sampled from a wide range of branches of service, trades and ranks. Therefore, it is believed that the glove fitting results obtained with the present sample are applicable to the CF as a whole As such, using the criteria for acceptable glove fit (see Section 3.1), only 78.2% of CF males and 69.7% of CF females met acceptable fit criteria with the in-service glove. For the male participants, the in-service glove sizing system failed at the larger sizes where excessive glove finger length was a consistent fit problem. The females predominantly used the extra-small glove size. In general, the in-service glove sizing system did not offer sizes that were small enough to provide acceptable fit for the females.

The one size of the prototype CB protective glove demonstrated quite a wide range of fit for male CF personnel -- 56.4% met acceptable fit criteria without the liner underlayer and 59.8% met the criteria with the liner and glove combination. In contrast, the highest male tariff for any one size with the in-service glove was 28.8% (medium size). Even if the male tariffs for the small, medium and large in-service glove sizes are considered collectively, the coverage provided -- i.e., 64.8% -- is only slightly greater than that provided by the one size prototype. Relative to the five sizes of the in-service glove, the unlined prototype glove size was located between the medium and large sizes.

The prototype glove size accommodated a large number of male CF personnel. This result can be attributed to the fact that the prototype size was well situated within the range of male CF hand dimensions. That is, without the liner underlayer the prototype glove size left approximately 15% of males in need of a larger glove and approximately 30% of males in need of a smaller glove size. With the liner underlayer, the split was almost even -- approximately 20% of males were in need of a larger glove size and approximately 20% of males were in need of a smaller glove size. The corrugations applied at various locations on the glove also likely contributed to the wide range of fit provided by the prototype glove size.

The overall fit ratings for the unlined and lined prototype gloves were comparable to those of the in-service glove. In terms of fit problem areas, male participants found the prototype glove finger lengths too long and the glove palm too large. These problems were very similar to those reported for the larger sizes of the in-service glove. Wearing the liner underlayer improved the fit of the prototype glove in finger girth -- i.e., decreased the reports of "too loose" fit in finger girth were evident when the liner was worn.

The prototype glove provided a very poor fit for female CF personnel. Only 21.3% of females met acceptable fit criteria with the unlined prototype, this number was almost identical to the range accommodated by lined prototype -- 21.9%. Even those females whose questionnaire responses met the acceptable fit criteria reported high frequencies

of fit problems The prototype glove was too large fitting in almost all glove areas for almost all of the female participants. This result for the females is not surprising given that the prototype glove size was situated between the medium and large in-service glove sizes and that only 9.0% of females met acceptable fit criteria with these sizes of the in-service glove.

These results suggest that the five-size system of the in-service CW lightweight glove is not appropriate for the prototype CB protective glove. They also reveal that the dimensions used for the prototype size are very effective in providing acceptable fit for a wide range of males, and that this size provides a reasonably central coverage zone for males. Therefore, the prototype size would be very effective as a central male glove size for the new CB protective glove. In terms of the female results, there is clearly room for improvement to the sizing and fit of the gloves for female CF personnel.

5. References

1. Tremblay, J. F., "Evaluation of Functional Fit and Comfort of Chemical Protective Gloves for Agricultural Workers", Masters Thesis, University of Alberta, Edmonton, Alberta, 1989.

2. Tremblay-Lutter, J. F. and Weihrer, S. J., "Functional Fit Evaluation to Determine Optimal Ease Requirements in Chemical Protective Gloves", Performance of Protective Clothing ASTM STP 1237, J. S. Johnson and S. Z. Mansdorf, eds., American Society for Testing and Materials, Philadelphia, pp. 367-383, 1996.

3. Tremblay-Lutter, J. F., Laurie, E., Weihrer, S.J., and Clark, J. "Acton's New CB Moulded Gloves that Fit and Do Not Tear, A Novel Idea", Proceedings of the Chemical and Biological Medical Treatment Symposia (CBMTS III), Spiez, Switzerland, May 7-12 2000.

4. Weihrer, S. J. and Tremblay-Lutter, J. F., "Canadian Forces Glove Fit Study: Anthropometric Survey and Definition of Canadian Forces Hand Dimensions", DRES TR 2000-002, Defence Research Establishment Suffield, Ralston, Alberta, Canada, In Preparation

5. Weihrer, S. J. and Tremblay-Lutter, J. F., "Canadian Forces Glove Fit Study: Development of an Integrated Anthropometric Sizing System for Chemical Biological Protective Gloves", DRES TR 2000-005, Defence Research Establishment Suffield, Ralston, Alberta, Canada, In Preparation.

6. Weihrer, S., "Documentation of the Development of the New Concept Glove Design", CR 1999-101, Defence Research Establishment Suffield, Ralston, Alberta, Canada, 1999.

7. Weihrer, S. and Rhodes, W., "Functional Fit Evaluation of the Chemical Protective Lightweight Glove", Contractor Report: 02/92, Defence Research Establishment Ottawa, Chemical Protection Section, Protective Sciences Division, Ottawa, Ontario, Canada, 1992.

8. Robinette, K. M. and Annis, J. F., "A nine-size system for chemical defense gloves", AAMRL-TR-86029, Harry G. Armstrong Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio, USA, 1986.

This page intentionally left blank.

Annex A
Glove fit questionnaires

This annex contains the questionnaires, both English-language and French-language versions, which were developed to gather qualitative information on the fit of three different handwear conditions: the CF in-service CW lightweight glove (green glove), the prototype glove (black glove), and the prototype glove worn with a liner (black glove with liner). The questionnaires used in the evaluation were printed on 8.5 by 14 inch paper. Note that the font size and spacing characteristics of the questionnaires in this annex have been reduced to fit onto 8.5 by 11 inch paper.

This page intentionally left blank.

FIT OF GREEN GLOVE

INSTRUCTIONS

Please try the available sizes of the green glove on your right hand and select from these five sizes one that you would feel most comfortable wearing for at least half a day while performing a variety of tasks

Move your hand around for a short time with this glove size on -- clench and unclench your fist, spread your fingers out and in, and move your fingers up and down one by one ***While you are still wearing the glove, please answer the following questions***

Circle the glove size chosen as best fitting **XS S M L XL**

Do you feel that the fit of this glove would allow you to perform most of your normal daily activities successfully?
☐ YES ☐ NO

Please rate the **overall fit** of the glove by **circling the number** along the scale below that corresponds to the most appropriate response for you

1	2	3	4	5	6	7
very good	good	somewhat good	neither good nor poor	somewhat poor	poor	very poor

Please check off any **fitting problems** you have with this glove size (check all that apply)

TOO SMALL	a little	a lot	TOO LARGE	a little	a lot
glove fingers too short	☐	☐	glove fingers too long	☐	☐
glove fingers too tight	☐		glove fingers too loose	☐	☐
glove palm too short	☐	☐	glove palm too long	☐	☐
glove palm too tight		☐	glove palm too loose	☐	☐
glove wrist too tight	☐		glove wrist too loose		☐
glove cuff too short	☐	☐	glove cuff too long	☐	☐
glove cuff too tight	☐	☐	glove cuff too loose	☐	☐

Comments

FIT OF BLACK GLOVE

INSTRUCTIONS

Please try the black glove on your right hand. There is only one size of this glove available so if you are not able to get this glove on, simply indicate this in your response to the first question below.

Move your hand around for a short time with this glove on -- clench and unclench your fist, spread your fingers out and in, and move your fingers up and down one by one. ***While you are still wearing the glove, please answer the following questions.***

Do you feel that the fit of this glove would allow you to perform most of your normal daily activities successfully?

☐ YES ☐ NO ☐ COULD NOT GET GLOVE ON

(skip the remaining questions if you could not get the glove on)

Please rate the **overall fit** of the glove by **circling the number** along the scale below that corresponds to the most appropriate response for you.

1	2	3	4	5	6	7
very good	good	somewhat good	neither good nor poor	somewhat poor	poor	very poor

Please check off any **fitting problems** you have with this glove (check all that apply)

TOO SMALL	a little	a lot	TOO LARGE	a little	a lot
glove fingers too short	☐	☐	glove fingers too long	☐	☐
glove fingers too tight	☐	☐	glove fingers too loose	☐	☐
glove palm too short	☐	☐	glove palm too long	☐	☐
glove palm too tight	☐	☐	glove palm too loose	☐	☐
glove wrist too tight	☐	☐	glove wrist too loose	☐	☐
glove cuff too short	☐	☐	glove cuff too long	☐	☐
glove cuff too tight	☐	☐	glove cuff too loose	☐	☐

Comments

_____

_____

_____

FIT OF BLACK GLOVE WITH A LINER

INSTRUCTIONS

Select a liner size that fits your right hand best from the four available sizes When selecting a size, keep in mind that the liner is designed to fit snugly on your hand

Circle the liner size chosen as best fitting S M L XL

Please rate the **overall fit** of the liner by **circling the number** along the scale below that corresponds to the most appropriate response for you

1	2	3	4	5	6	7
very good	good	somewhat good	neither good nor poor	somewhat poor	poor	very poor

Put the black glove on over the liner on you right hand. If you are not able to get this glove on over the liner, simply indicate this in your response to the first question below Move your hand around for a short time with the liner and glove on -- clench and unclench your fist, spread your fingers out and in, and move your fingers up and down one by one ***While you are still wearing the liner and glove, please answer the following questions***

Do you feel that the fit of this glove system (liner and glove) would allow you to perform most of your normal daily activities successfully? [ ] YES [ ] NO [ ] COULD NOT GET BLACK GLOVE ON OVER LINER

(skip the remaining questions if you could not get the glove on over the liner)

Please rate the **overall fit** of this glove system by **circling the number** along the scale below that corresponds to the most appropriate response for you

1	2	3	4	5	6	7
very good	good	somewhat good	neither good nor poor	somewhat poor	poor	very poor

Please check off any **fitting problems** you have with this glove system (check all that apply)

	TOO SMALL			TOO LARGE	
	a little	a lot		a little	a lot
glove fingers too short	[ ]	[ ]	glove fingers too long	[ ]	[ ]
glove fingers too tight	[ ]		glove fingers too loose	[ ]	[ ]
glove palm too short	[ ]	[ ]	glove palm too long	[ ]	[ ]
glove palm too tight	[ ]	[ ]	glove palm too loose	[ ]	[ ]
glove wrist too tight	[ ]	[ ]	glove wrist too loose	[ ]	[ ]
glove cuff too short	[ ]	[ ]	glove cuff too long	[ ]	[ ]
glove cuff too tight	[ ]	[ ]	glove cuff too loose	[ ]	[ ]

Comments

AJUSTEMENT DU GANT VERT

INSTRUCTIONS

Essayer les cinq gants verts et choisir celui avec lequel vous vous sentiriez le plus confortable si vous aviez à le porter durant au moins une demi-journée afin d'exécuter des tâches variées

Pour ce faire, faites bouger votre main, serrez et desserrez votre poing, écartez et rapprochez vos doigts, et faites-les bouger un à la fois ***Remplir le questionnaire suivant en portant le gant***

Encercler la taille du gant qui vous convient le mieux	XS (Très Petit)	S (P)	M (M)	L (G)	XL (Très Grand)

Estimez-vous que ce gant pourrait vous permettre de bien exécuter la plupart de vos tâches quotidiennes normales? OUI NON

Choisir à quel degré le gant vous convient en encerclant un nombre sur l'échelle ci-dessous

1	2	3	4	5	6	7
très bien	bien	assez bien	de façon moyenne	assez mal	mal	très mal

Indiquer tous les problèmes particuliers qui pourraient, d'après vous, s'appliquer à ce gant

TROP PETIT	un peu	beaucoup	TROP GRAND	un peu	beaucoup
doigts du gant trop courts			doigts du gant trop longs		
doigts du gant trop serrés			doigts du gant trop grands		
paume du gant trop courte			paume du gant trop longue		
paume du gant trop serrée			paume du gant trop grande		
poignet du gant trop serré			poignet du gant trop grand		
avant-bras du gant trop court			avant-bras du gant trop long		
avant-bras du gant trop serré			avant-bras du gant trop grand		

Commentaires

_____

_____

AJUSTEMENT DU GANT NOIR

INSTRUCTIONS

Essayer le gant noir (dont une seule grandeur n'est disponible) Si vous vous trouvez incapable d'y glisser votre main, veuillez l'indiquer en réponse à la première question ci-dessous

Pour ce faire, faites bouger votre main, serrez et desserrez votre poing, écartez et rapprochez vos doigts, et faites-les bouger un à la fois ***Remplir le questionnaire suivant en portant le gant***

Estimez-vous que ce gant pourrait vous permettre de bien exécuter la plupart de vos tâches quotidiennes normales?

OUI NON IMPOSSIBLE D'Y GLISSER LA MAIN

(ne pas répondre aux questions suivantes s'il vous a été impossible d'enfiler le gant)

Choisir à quel degré le gant vous convient en encerclant un nombre sur l'échelle ci-dessous

1	2	3	4	5	6	7
très bien	bien	assez bien	de façon moyenne	assez mal	mal	très mal

Indiquer tous les problèmes particuliers qui pourraient, d'après vous, s'appliquer à ce gant

TROP PETIT	un peu	beaucoup	TROP GRAND	un peu	beaucoup
doigts du gant trop courts	[ ]	[ ]	doigts du gant trop longs	[ ]	[ ]
doigts du gant trop serres	[ ]	[ ]	doigts du gant trop grands	[ ]	[ ]
paume du gant trop courte	[ ]	[ ]	paume du gant trop longue	[ ]	[ ]
paume du gant trop serrée	[ ]	[ ]	paume du gant trop grande	[ ]	[ ]
poignet du gant trop serré	[ ]	[ ]	poignet du gant trop grand	[ ]	[ ]
avant-bras du gant trop court	[ ]	[ ]	avant-bras du gant trop long	[ ]	[ ]
avant-bras du gant trop serré	[ ]	[ ]	avant-bras du gant trop grand	[ ]	[ ]

Commentaires

_____

_____

_____

AJUSTEMENT DU GANT NOIR AVEC UNE DOUBLURE

INSTRUCTIONS

Essayer les quatre doublures et choisir celle qui convient le mieux à la taille de votre main En choisissant la grandeur la plus appropriee, considérer le fait qu'une telle doublure doit être portée bien ajustée (assez serrée)

Encercler la taille du gant qui vous convient le mieux	S (Petit)	M (M)	L (G)	XL (Très Grand)

Choisir a quel degré la doublure vous convient en encerclant un nombre sur l'échelle ci-dessous

1	2	3	4	5	6	7
très bien	bien	assez bien	de façon moyenne	assez mal	mal	très mal

Enfiler le gant noir par-dessus la doublure Si vous vous trouvez incapable de glisser le gant noir par-dessus la doublure, veuillez l'indiquer en réponse à la première question ci-dessous

En portant le gant et la doublure, faites bouger votre main, serrez et desserrez votre poing, écartez et rapprochez vos doigts, et faites-les bouger un à la fois ***Remplir le questionnaire suivant en portant le gant et la doublure.***

Estimez-vous que cet ensemble (gant et doublure) pourrait vous permettre de bien exécuter la plupart de vos tâches quotidiennes normales?

☐ OUI ☐ NON ☐ IMPOSSIBLE DE GLISSER LE GANT PAR DESSUS LA DOUBLURE

(ne pas répondre aux questions suivantes s'il vous a été impossible d'enfiler le gant)

Choisir à quel degré l'ensemble (gant-doublure) vous convient en encerclant un nombre sur l'échelle ci-dessous

1	2	3	4	5	6	7
très bien	bien	assez bien	de façon moyenne	assez mal	mal	très mal

Indiquer tous les problèmes particuliers qui pourraient, d'après vous, s'appliquer à ce gant et doublure ensemble

TROP PETIT	un peu	beaucoup	TROP GRAND	un peu	beaucoup
doigts du gant trop courts	☐	☐	doigts du gant trop longs	☐	☐
doigts du gant trop serrés	☐	☐	doigts du gant trop grands	☐	☐
paume du gant trop courte	☐	☐	paume du gant trop longue	☐	☐
paume du gant trop serrée	☐	☐	paume du gant trop grande	☐	☐
poignet du gant trop serré	☐	☐	poignet du gant trop grand	☐	☐
avant-bras du gant trop court	☐	☐	avant-bras du gant trop long	☐	☐
avant-bras du gant trop serré	☐	☐	avant-bras du gant trop grand	☐	☐

Commentaires

Annex B
Glove photographs

This page intentionally left blank.

Figure B-5.1. Five sizes of in-service CW lightweight gloves

Figure B-5.2. One size prototype CB protective glove

Figure B-5.3. Medium size in-service CW lightweight glove (left), prototype CB protective glove (middle) and large size in-service CW lightweight glove (right).

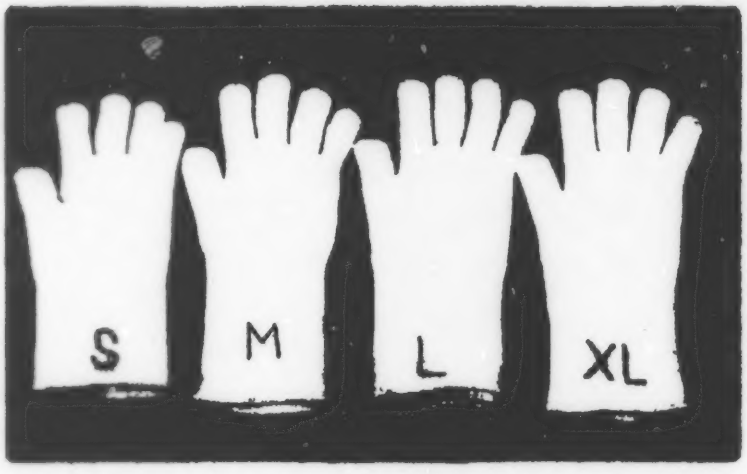


Figure B-5.4. Glove liner – four sizes.

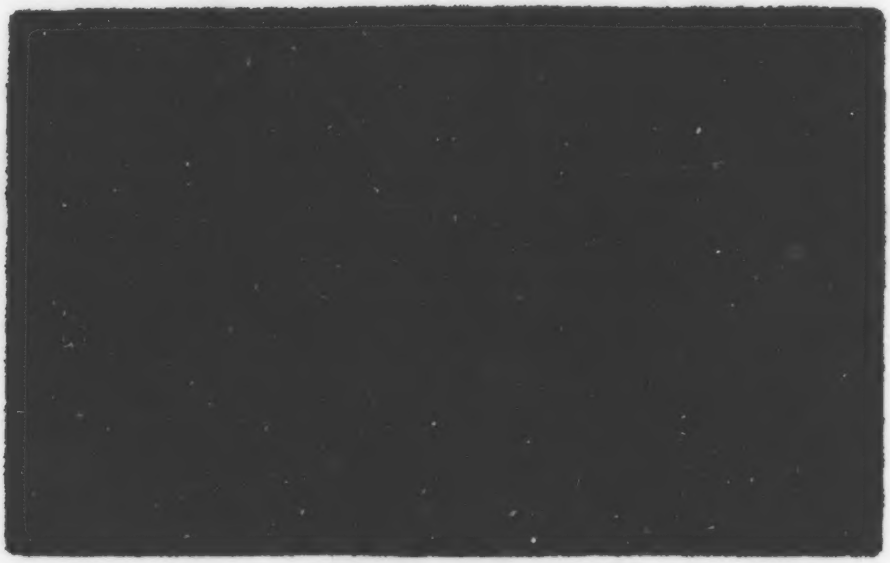


Figure B-5.5. Liner size selection at CFB Halifax

Figure B-5.6. Prototype glove evaluation at CFB Halifax

This page intentionally left blank.

Distribution list

DRES	J.F. Tremblay-Lutter
DCIEM	Walter Dyck
DRDCIM	
DNBCD	
DNBCD 2	LCol Schlosser R.M.
DNBCD2-4	Maj G McNally
DSSPM 2	Judith Spanglett
DSSPM 2-3	Margaret Mech
DLR	Capt Poehlmann

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for who the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in Section 8.)

DRES

2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable)

UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title).

CANADIAN FORCES GLOVE FIT STUDY: FIT ASSESSMENT OF IN-SERVICE CW LIGHTWEIGHT GLOVE AND MOLDED GLOVE PROTOTYPE

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

WEIHRER, SYLVIA J. AND TREMBLAY-LUTTER, JULIE F

5. DATE OF PUBLICATION (month and year of publication of document)	6a. NO. OF PAGES (total containing information, include Annexes, Appendices, etc)	6b NO. OF REFS (total cited i document)
September 2000	87	8

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum If appropriate, enter the type of report, e. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Memorandum
TECHNICAL REPORT

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

HAZARD AVOIDANCE SECTION, DEFENCE RESEARCH ESTABLISHMENT SUFFIELD P.O. BOX 4000, MEDICINE HAT ALBERTA T1A 8K6

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
OLD 6FA13	
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NOs (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally corresponded to the Docum Availability (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected).

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C) or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

THE CANADIAN FORCES (CF) GLOVE FIT STUDY WAS UNDERTAKEN IN ORDER TO DEVELOP A DATABASE OF HAND DIMENSIONS FOR MALE AND FEMALE CF PERSONNEL THAT COULD BE APPLIED TO THE DEVELOPMENT OF A NEW CHEMICAL BIOLOGICAL (CB) PROTECTIVE GLOVE. ANOTHER COMPONENT OF THE STUDY WAS TO EVALUATE THE RANGE AND QUALITY OF FIT PROVIDED BY THREE PROTECTIVE GLOVE SYSTEMS: THE IN-SERVICE LIGHTWEIGHT CHEMICAL WARFARE (CW) GLOVE, A PROTOTYPE CB PROTECTIVE GLOVE, AND THE PROTOTYPE GLOVE WORN WITH A LINER UNDER LAYER. A TOTAL OF 358 MALE CF PERSONNEL AND 178 FEMALE CF PERSONNEL PARTICIPATED IN THE CF GLOVE FIT STUDY. THE STUDY WAS UNDERTAKEN IN THREE PHASES: DEFINITION OF THE HAND DIMENSIONS OF THE CF POPULATION; INVESTIGATION OF THE FUNCTIONAL DESIGN AND USER-ACCEPTABILITY OF THE IN-SERVICE AND NEW CB GLOVE; INTEGRATION OF HAND DIMENSIONS IN A COMPUTER MODEL TO REPRESENT AN END-USER POPULATION. THIS REPORT PRESENTS RESULTS FROM THE FUNCTIONAL FIT INVESTIGATION OF THE IN-SERVICE LIGHTWEIGHT CF CB PROTECTIVE GLOVE AND A PROTOTYPE MOLDED GLOVE.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

HAND MEASUREMENTS, FOREARM MEASUREMENTS, ANTHROPOMETRIC SURVEY, GLOVES, GLOVE FIT EVALUATION, CHEMICAL PROTECTIVE GLOVES